LAWES AGRICULTURAL TRUST

Rothamsted Experimental Station
Harpenden

REPORT 1921-22

with the

Supplement

to the

"Guide to the Experimental Plots"

containing

The Yields per Acre, etc.

To be obtained only of the Secretary

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The New Rothamsted Laboratories, erected 1914-1916

Contents

Experimental Station Staff

(On July 1st, 1923)

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Assistant Director : B. A. Keen, D.Sc., F.Inst.P.

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Laboratory Attendant ...	Annie Mackness.

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	A. T. Legg.
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	R. G. Warren, B.Sc.
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	N. Gangulee, B.Sc. (Prof. Agric. Univ. Calcutta).
Barley Investigations (Institute of Brewing Research Scheme)	H. Lloyd Hind, B.Sc., F.I.C

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Assistant Physical Chemist	E. M. CROWTHER, M.Sc., A.I.C. (Empire Cotton Corporation Soil Physicist)
Assistant Physicists ...	W. B. HAINES, B.Sc., F.Inst.P. J. R. H. COUTTS, B.Sc.
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Assistant Statistician ...	Winifred Mackenzie, B.Sc. (Econ.)
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Laboratory Assistant ...	A. D. Dunkley.

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Woburn Experimental Farm.

Hon. Local Director: J. A. Voelcker, M.A., Ph.D.

Leadon Court.

(The property of E. D. Simon, Esq.)

Manager: J. C. Brown, F.S.I.

Publications of the Rothamsted Experimental Station

For Farmers

"The Book of the Rothamsted Experiments," by Sir A. D. Hall, M.A. (Oxon), F.R.S., Third Edition revised by Sir E. J. Russell, D.Sc., F.R.S. John Murray, 50, Albermarle Street, London, W.1. (in preparation).

"Manuring for Higher Crop Production," by E. J. Russell, 1917. The University Press, Cambridge. 5/6

"Weeds of Farmland," by Winifred E. Brenchley, D.Sc., F.L.S., 1920. Longmans, Green & Co., 39, Paternoster Row, London, E.C.4. 12/6

"Farm Soil and its Improvement," by E. J. Russell, 1923. Benn Bros., Ltd., 8, Bouverie Street, London, E.C.4.

For Students and Agricultural Experts

"The Rothamsted Memoirs on Agricultural Science," Quarto Series, vols. 1-3 (1859-1883), 20/- each. Octavo, vols. 1-7 (1847-1898), 30/- each. Royal octavo, vol. 8 (1900-1912), vols. 9 and 10 (1909-1920), 32/6 each. Obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

"The Rothamsted Monographs on Agricultural Science," edited by Sir E. J. Russell, D.Sc., F.R.S. Longmans, Green & Co., 39 Paternoster Row, London, E.C.4.

> "Soil Conditions and Plant Growth," by E. J. Russell, Fourth Edition, 1921. 16/-
>
> "The Micro-Organisms of the Soil," by E. J. Russell and Staff of the Rothamsted Experimental Station, 1923. 7/6

The following Monographs are in preparation:—

> "Soil Physics," by B. A. Keen, D.Sc.
>
> "Soil Protozoa," by D. W. Cutler, M.A., and Lettice M. Crump, M.Sc.
>
> "Soil Bacteria," by H. G. Thornton, B.A.
>
> "Soil Fungi and Algæ," by W. B. Brierley, D.Sc., and B. Muriel Bristol, D.Sc.
>
> "Chemical Changes in the Soil," by H. J. Page, B.Sc.

"Inorganic Plant Poisons and Stimulants," by Winifred E. Brenchley, 1914. The University Press, Cambridge. 9/-

"The Manuring of Grassland for Hay," by Winifred E. Brenchley, D.Sc. Longmans, Green & Co., 39 Paternoster Row, London, E.C.4 (in the press).

"A General Textbook of Entomology," by A. D. Imms, D.Sc. Methuen & Co., Essex Street, Strand, London, W.C.2 (in the press).

The following are obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts :—

"Agricultural Investigations at Rothamsted, England, during a period of 50 years," by Sir Joseph Henry Gilbert, M.A., LL.D., F.R.S., etc., 1895. 3/6

"Six Lectures on the Investigations at Rothamsted Experimental Station," by Robert Warington, F.R.S., 1891. 2/-

"Guide to the Experimental Plots, Rothamsted Experimental Station, Harpenden." 1913. John Murray, 50 Albermarle Street, W. 1/-

"Plans and Data of the Experimental Plots." 1923. 6d.

For use in Farm Institutes

"A Student's Book on Soils and Manures," by E. J. Russell, 1919. The University Press, Cambridge. 8/-

For use in Schools

"Lessons on Soil," by E. J. Russell, 1912. The University Press, Cambridge. 3/-

For General Readers

"The Fertility of the Soil," by E. J. Russell, 1913. The University Press, Cambridge. 4/-

"Personal Reminiscences of Rothamsted Experimental Station," 1872-1922, by E. Grey, Superintendent of the Experimental Fields. 5/-. Obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

INTRODUCTION

The Rothamsted Experimental Station was founded in 1843 by the late Sir J. B. Lawes, with whom was associated Sir J. H. Gilbert for a period of nearly 60 years. Lawes died in 1900 and Gilbert in 1901; they were succeeded by Sir A. D. Hall from 1902 to 1912, when the present Director, Dr. E. J. Russell, was appointed.

For many years the work was maintained entirely at the expense of Sir J. B. Lawes, at first by direct payment, and from 1889 onwards out of an income of £2,400, arising from the endowment fund of £100,000 given by him to the Lawes Agricultural Trust. In 1904 the Society for extending the Rothamsted Experiments was instituted for the purpose of providing funds for expansion. In 1906 Mr. J. F. Mason built the Bacteriological Laboratory; in 1907 the Goldsmiths' Company generously provided a further endowment of £10,000, the income of which is to be devoted to the investigation of the soil, thus raising the total income of the Station to £2,800. In 1911 the Development Commissioners made their first grant to the Station. Since then Government grants have been made annually, and for the year 1922-23 the Ministry of Agriculture have made a grant of £22,030 for the work of the Station. Viscount Elveden, M.P., has generously borne the cost of a chemist for studying farmyard manure since 1913, and until his death the late Mr. W. B. Randall defrayed the salary of a biologist. The Sulphate of Ammonia Federation and the Fertiliser Manufacturers' Association jointly defray the cost of a Guide Demonstrator for the field plots.

The laboratories have been entirely rebuilt. The main block was opened in 1919, and is devoted to the study of soil and plant nutrition problems; a new block is being erected for plant pathology. The library has been much expanded and now contains some 20,000 volumes dealing with agriculture and cognate subjects. The equipment of the farm has also been expanded.

The most important development of recent years has been the reorganisation of the work of the Station so as to bring it into touch with modern conditions of agriculture on the one side and of science on the other. The general organisation of the laboratory is now completed; it is hoped to reorganise in the near future the farm and field work and to improve the field technique.

The general method of investigation at Rothamsted is to start from the farm and work to the laboratory, or *vice versa*.

There are four great divisions in the laboratory—biological, chemical, physical and statistical—which may be regarded as the pillars on which the whole structure rests. But the method of investigation differs from that of an ordinary scientific laboratory where the problem is usually narrowed down so closely that only one factor is concerned. On the farm such narrowing is impossible; many factors may operate and elimination results in conditions so artificial as to render the enquiry meaningless. In place, therefore, of the ordinary single factor method of the

scientific laboratory, liberal use is made of statistical methods which allow the investigation of cases where several factors vary simultaneously. Thus in the crop investigations a large number of field observations are made; these are then treated statistically to ascertain the varying degrees to which they are related to other factors—such as rainfall, temperature, etc.—and to indicate the probable nature of the relationships. Thus the complex problem becomes reduced to a number of simpler ones susceptible of laboratory investigation.

It has been found desirable to widen the scope of the work by repeating some of the more important experiments elsewhere, and some twenty centres in different parts of the country have been selected for this purpose.

In October, 1921, the Station undertook, so long as its funds should allow, to carry on the continuous wheat and barley experiments at the Woburn Experimental Farm, till then conducted by the Royal Agricultural Society, and Dr. Voelcker gives his services as Honorary Local Director. In December, 1922, E. D. Simon, Esq., generously placed his Leadon Court farm at the disposal of the Station for experimental purposes. This is being used as a large scale test of the soiling system for keeping dairy cows (see p. 26).

REPORT FOR THE YEARS 1921-22

In order to appreciate properly the Rothamsted experiments, it is necessary to understand the purpose for which they are carried out. This purpose is to discover the principles underlying the great facts of agriculture and to put the knowledge thus gained into a form in which it can be used by teachers, experts and farmers for the upraising of country life and the improvement of the standard of farming.

The most fundamental part of agriculture is the production of crops, and to this most of the Rothamsted work is devoted. On the technical side the problems fall into three groups, concerned respectively with the cultivation of the soil, the feeding of the crops, and the maintenance of healthy conditions of plant growth. The subjects will be taken in this order.

THE CULTIVATION OF THE SOIL.

Cultivation has been reduced to a fine art, and a good farmer independent of financial considerations could obtain very satisfactory results without consulting the scientific worker. In practice, however, costs dominate the situation, and efforts are continuously being made to cut them down. Scientific investigation of all cultivation processes therefore becomes necessary. This is done in the Physical Department under Dr. Keen; the effects produced

by the cultivation processes are investigated, especially those concerned with tilth, water supply and resistance to the passage of implements; and the actual working of typical implements is studied by means of dynamometer tests so as to see what power is required to do a given piece of work and how this is affected by the design of the implement. The first of these enquiries is needed to find out exactly what work has to be done and, if possible, to state the result in engineering terms; the second shows how far our present types of implements are efficient, and if they are not, where the wastage of power occurs.

It is fully recognised that the nature of the soil largely determines the amount of power required to do certain cultivation work. The measurements are showing that the farmer can alter his own soil so as to reduce the power requirement. Thus, on our heavy soil at Rothamsted the drawbar pull on a plough turning three furrows is of the order of 1,500 lb. and the "power factor" (*i.e.*, drawbar pull in lb. multiplied by time in seconds taken to plough 1 ft. length of furrow) is of the order of 550. But when the land is chalked there is a saving of power, which may vary from almost nothing up to 15%, according to the condition of the soil. The following are some of the data:—

Field and Date	Drawbar pull in lb.			Percentage Reduction in power factor due to Chalking
	Unchalked	Chalked	Reduction due to Chalking	
SAWPIT. Stubbles: Autumn; dry . .	473	476	Difference not significant	Nil
Cross ploughing weathered furrows Spring . . .	521	461	60	11.5
GREAT KNOTT. Oct.	924	802	122	14.7
January: very wet	1258	1181	77	4.6

When the land is very dry or very wet, the chalking shows its effects least, but in moist conditions it acts strikingly.

Farmyard manure and coarse ashes also reduce the power requirement in ploughing. On Hoos field the reduction has been, as compared with unmanured soil:—

Due to Farmyard Manure	*Coarse Ashes*
22.6%	12.3%

(values for unmanured soil: drawbar pull = 1,472 lb.; power factor = 614.)

Even artificial manures have some action. This has been studied in the first instance on the Broadbalk wheat field where, however, the effects are much intensified from the circumstance that the same manures are applied year after year. The reduction in power requirement brought about by the use of artificial manures has been:—

FULL MINERALS, AND, IN ADDITION:—

No Nitrogen Plot 5	Sulph/ammonia 200lb. per acre Plot 6	Sulph/ammonia 400lb. per acre Plot 7	Sulph/ammonia 600lb. per acre Plot 8	Nitrate/soda 275lb. per acre Plot 9
14.2%	12.7%	16.3%	21.5%	8.1%

when compared with the unmanured plot.

The mineral manures have caused some reduction in power requirement, and a still further reduction has been caused by addition of sulphate of ammonia, but nitrate of soda has acted the other way and increased the power requirement.

There are, however, other ways of altering the resistance of soil to the plough, and an interesting electrical method is being studied.

The depth of ploughing influences the power consumption more than might have been expected. An increase of only one inch in depth, *i.e.*, going from 5″ to 6″ deep, increased the power consumption no less than 32%, a portion of which is due to the resistance offered by the "plough-sole" produced below 5″ depth. Against this, maladjustments of the hitch were not particularly wasteful of power, although they caused bad ploughing. Perhaps the most surprising result was that the drawbar pull was practically the same whatever the speed of ploughing within the ordinary limits of the tractor; hence the power consumption per acre depends mainly on the speed and is smallest at the highest speeds. Another way of stating this fact is that the paraffin consumption per hour for the same tractor is approximately the same whether it is taking 1½ hours or 3 hours to plough an acre of ground.

The factors determining the resistance and the power consumption are intimately bound up with the physical properties of the soil which are systematically studied in the Physical Department. These physical properties determine also the water relationships—evaporation of water, percolation, etc.—which are being carefully investigated. This work has important applications in tropical and sub-tropical countries where irrigation is practised, and the Indian Government regularly sends experts to study for a year or two in the Physics Department.

Dr. Keen is also co-operating with Professor Sven Odén, of Stockholm, in elaborating the original Odén apparatus for estimating the amount of fine material of different sizes in soils.

SOIL ACIDITY.

The electrometric method used in the Physics Department by Mr. E. M. Crowther is giving good results and is sharply distinguishing soils of varying degrees of acidity. The values are

labelled pH, and the lower they are the greater the degree of acidity. Thus the following Garforth soils have been tested :—

	pH value
Very acid, wheat bad	4.37
Less acid, wheat poor	4.44
Still less acid, wheat better	4.65
Still less acid, wheat good	4.82

Another set gave these results :—

Acid, finger and toe prevalent on turnips .	5.64
Less acid, no finger and toe	6.13

It is also shown that there is a closer relationship between the pH values and the Hutchinson-McLennan "Lime requirement" values than might have been expected, and the latter afford useful guidance in placing similar soils in order of acidity.

THE FEEDING OF THE PLANT.

Farmers are now thoroughly familiar with the fact that the production of heavy crops necessitates a skilful and adequate use of fertilisers. In spite of the severe agricultural depression of the past two years, there has been a considerable consumption of fertilisers : in some cases greater than in pre-war times ; this is shown in the following table :—

AVAILABLE SUPPLIES OF FERTILISERS IN TONS: GREAT BRITAIN AND IRELAND. (1)

(1) Min. Ag. Statistics, 1921, Vol. LVI, p. 107 and private communication. No information is available as to actual consumption on farms or as to stocks carried over from one year to another.

	1912	1918	1919	1920	1921	1922
Sulphate of Ammonia	60,000	250,000	240,000	240,000	112,000	147,000
Nitrate of Soda .	100,000	9,000	40,000	100,000*	55,000*	33,000*
Superphosphate .	700,000	650,000	580,000	660,000	450,000	515,000
Basic Slag . .	300,000	550,000	485,000	550,000	210,000	283,000†
Potash Salts (including Muriate and Sulphate of Potash) . . .	80,000	5,000	50,000	125,000	53,000	201,000

* Net imports for all purposes. † Ignoring imports and exports.

Artificial manures influence not only the amount but also the character of the plant growth, and very often the quality of the produce. So long as farmers were confined mainly to farmyard manure they could and did discover for themselves its effects on the crop. But there are now more than thirty manures available for the farmer, and an ingenious chemist could make up over 6,000 different recipes for the potato crop alone, to say nothing of the mixtures required for other crops on the farm ; and to add to the complexity of the matter no manure acts in quite the same way on two different farms, while even on the same farm the effect may vary considerably from season to season. Hence the need for experimental work to discover the general rules by which to guide farmers as to the most suitable of the possible mixtures.

The experimental work falls under two headings :—

1. The influence of fertilisers on the yield of crops under different conditions of soil and climate ;
2. Their effect in altering the composition or quality of the crop.

The effect of fertilisers on crop yield is studied in three ways. The most direct and accurate is the method of water cultures and pot cultures used in the Botanical Department. Here the conditions are so rigidly controlled that the factors, except the one under investigation, are kept as nearly constant as possible. The results are plotted on curves which, if they pass certain statistical tests, can be used as a basis for physiological deductions. Experiments of this kind have shown that the plant responds to two kinds of added substances : the usual nitrogen, phosphorus and potassium compounds required in rather large amounts ; and certain substances not yet fully known, which are required in very small amounts only. Agricultural chemists and farmers are familiar with the use of the former, but not of the latter.

Dr. Winifred Brenchley has already studied certain cases, notably manganese, and this year Miss Warington showed that broad beans and certain other leguminous plants die prematurely unless they receive a small quantity of boric acid in addition to the so-called "complete" plant food. The results suggest that some of the anomalies and unexpected failures in fertiliser experience may be traceable to the absence of some of these substances required in homeopathic doses only. But we must caution farmers that this work is still a long way from practical application and they must on no account be beguiled into buying "catalytic" or "radioactive" fertilisers in the hope of getting something outside the usual fertiliser constituents. We have tested several of these supposed "radioactive" fertilisers, but failed to obtain any benefit from them.

This method of experiment is invaluable where the factors can be controlled, but otherwise it breaks down. For this reason it does not give entirely reliable guidance for field practice where the weather conditions are entirely uncontrollable, and it completely fails to show how weather conditions influence the efficiency of the various fertilisers. A second method is therefore adopted. The Rothamsted data, extending as they do over a long series of years, can be subjected to modern methods of mathematical analysis. The variation in crop yield from season to season is traced to two types of causes : (*a*) annual, the variation in each season being independent of the years before and after, *e.g.*, weather ; (*b*) continuous acting, of which there are two forms, steady, such as soil-deterioration, and variable, such as weed infestation. Mr. Fisher has devised methods for finding out how much of the variation is due to each of these causes, and has been able to trace out the average effect of rain above or below the average in amount in each month of the plant's life.

Methods are being developed to find out how much the crop yield is likely to be altered by deviations from the average weather and other conditions, and important results may emerge. There must always be a risk about crop yields whatever steps the farmer may take. At present the risks are entirely speculative.

It is hoped as a result of this work that they may become calculable and therefore insurable, just as is the risk of death. We want to be able to say to farmers, "If your soil and weather conditions are of a certain kind, the chances are so many to one that a specified fertiliser mixture will give an increased crop of so many tons or bushels per acre." The difficulties of the work are very great, but they are being steadily overcome.

Meanwhile, however, the farmer urgently needs precise information about fertilisers, and it becomes necessary to adopt a third method which, though not as accurate as the single factor or the statistical methods already described, nevertheless gives some of the information desired. This consists in repeating a field experiment as exactly as possible at a number of centres carefully chosen to represent important soil and climatic conditions. For example, a Wold farmer sees our experiments, and asks if he could get the same results on his own farm. At present we cannot say, because we do not know the effect of differences in soil type and climatic conditions; but this can be ascertained by repeating one of our typical experiments on a typical Wold farm and then comparing the results with our own. This is being done on some 20 carefully selected farms in different parts of the country.

FERTILISER INVESTIGATIONS.

In addition to field and pot tests these necessitate a considerable amount of chemical work, which is carried out in the Chemical Department under Mr. Page.

THE NEW NITROGENOUS MANURES.—UREA.

Our experiments indicate that this substance has a value between that of nitrate of soda and sulphate of ammonia. In addition it has two attractive features—it is highly concentrated and it exerts no harmful influence on the soil (p. 93, p. 101).

AMMONIUM CHLORIDE.

Experiments made in the past two seasons at Rothamsted and the outside centres show that the yields from ammonium chloride, when those from ammonium sulphate containing an equal amount of nitrogen are put at 100, are:—

	1921		1922	
	Rothamsted	Average of all outside centres	Rothamsted	Average of all outside centres
Cereals	104	117, 91 *	103	99
Potatoes	112	112, 85 *	110†	98
Mangolds	95	95		98

* Two groups of results in each case. † With dung. The value without dung was 99.

Examined in detail the results appear to fall into two groups. In both years the larger number of the values fall between 90 and 100, but a second group of values falls distinctly above 100. The indications are that ammonium chloride would generally be about 5 to 10% less effective than ammonium sulphate containing the same amount of nitrogen, but in some circumstances, which we cannot yet define, it may be somewhat more effective.

THE NEW BASIC SLAGS AND MINERAL PHOSPHATES.

The object of these experiments is to compare the respective fertiliser values of the old Bessemer slags, the more modern open-hearth slags, some of which are of high and some of low solubility in the official citric acid solution, and the mineral phosphates.

The general result up to the present is that the high soluble slags are quicker in action and more effective than those of low solubility, but the low soluble slags are more effective than their solubility indicates. These effects are seen in their simplest form in pot experiments where all conditions of growth are carefully controlled. In the field, however, the effects may be masked by various factors, such as water supply, temperature, etc.

A comparison made in 1922 gave the following results:—

	Pot Experiments	Field Experiments			
		Turnips		Barley	
	All crops 1922	Tons per acre	Per cent.	Bushels per acre	Per cent.
Open hearth slags					
90% soluble .	114	24.3	108	27	80
30% soluble .	106	23.3	104	29	85
Mineral phosphates: Gafsa	109	23.2	103	27.6	81
Nauru	101	22.3	99	—	—
Control . .	100	22.5	100	34	100

The turnip results in the field fall into line with those of the pot experiments, although the differences are probably within the experimental error, but the barley results fall out altogether. Inspection of the growing crops, however, showed that up to the end of June the appearance of the barley plants accorded with the pot experiments, but all this was lost before harvest.

In the grass experiments two distinct cases arise:—

1. If the herbage is poor, and the growth poor, the slags may increase the yield of hay;
2. If the grass is better and gives larger crops of hay, the slags may not increase the yield, though they may increase the amount of clover and thus improve the quality.

This is seen on inspection or on botanical analysis, or, better still, by a grazing test. The following results were obtained in the last two seasons:—

I. POOR GRASS LAND: 11 CWT. HAY ONLY PER ACRE.

	1922 *Cwt. per Acre.*
Control	10.9
Open hearth slag, 90% soluble . . .	16.5
,, ,, ,, 30% soluble . . .	18.7
Gafsa phosphate	18.8

II. BETTER GRASS LAND: 1-1½ TONS HAY PER ACRE.*

	Yield of Hay cwt. per acre		Live weight increase in Sheep, lb. per acre	
	1921	1922	1921	1922
Bessemer slag . .	24.3	17.3	59	143
Open hearth, high sol.	23.9	16.6	43.3	112
Control . . .			59	116
Open hearth, low sol.	26.5	21.1	67.3	123
Gafsa	25.4	22.5	88	107
Control . . .	26.4	20.1	90	115

* The slags used on the grazing land were not identical with those used on the hay land, but they were of similar types.

Inspection shows that the amount of clover is highest on Bessemer slag plots. There is less on the high soluble open hearth slag, still less on the low soluble slag and Gafsa plots, and least of all on the unmanured. The effects are beginning to show in the live weight increases.

THE POTASSIC FERTILISERS.

A beginning has been made with a test of the new potassic fertilisers, especially on the potato crop.

In 1921 the crop yields were very poor, owing to the drought; the advantage of potash showed, however, in keeping the plants alive some time after those on the "no potash" plots had died. In 1922 the yields were much better; the chloride gave practically the same yield as the sulphate. When, however, salt was present in addition to the chloride there was a drop in yield, especially where no dung was supplied. Taking the yields with potassium sulphate as the standard, the results were, for the potato crop:—

	Rothamsted		Other Centres	
	Dung	No Dung	Dung	No Dung
Potassium sulphate .	100	100	100	100
Potassium chloride alone . . .	98	106	99	104
Pot/chlor. plus salt: pure	100	96	—	—
Pot/manure salts (20% K_2O) . .	—	—	94	—
Sylvinite . . .	—	—	93	82
Kainit	—	—	92	88

The experiments are being continued.

MAGNESIUM SALTS AS FERTILISERS.

Field experiments made in 1922 with magnesium sulphate indicate that while apparently ineffective in ordinary conditions (apart from the potash-starved plots at Rothamsted), it has, in certain farming conditions, a considerable fertilising value :—

EFFECT OF MAGNESIUM SULPHATE ON THE YIELD OF POTATOES RECEIVING POTASSIUM SULPHATE.

	Rothamsted	Armstrong College Centres			
		Blaydon		Walbottle	
		Dung	No Dung	Dung	No Dung
Complete manure and—					
No magnesium sulphate .	100	100	100	100	100
Magnesium sulphate (a) .	102	114	108	129	118
(b) .	97	—	—	—	—

(a) Sulphate of potash used in complete manure.
(b) Muriate of potash used in complete manure.

We cannot at present explain this result, but the experiment is being repeated.

ARTIFICIAL FARMYARD MANURE.

This material is now being made at a number of centres and on a large scale. Some 2,000 tons of straw, in lots varying up to 80 tons in quantity, have now been treated under the direction of Messrs. E. H. Richards and R. L. Amoore on different farms in the country—mostly in the Eastern Counties. The material has been considerably improved by the introduction of phosphates, but there remain difficulties connected with the wetting of the straw. The product is not yet up to a good sample of true farmyard manure, but it is being steadily improved, and the 1922 results are distinctly promising. The following is a large scale test made by the Chelmsford Institute with potatoes on an Essex farm :—

	No Manure			Artificials only			Artificials plus Cow Manure			Artificials plus Straw Manure		
	Tons	Cwts.	Qrs.	Tons	Cwts.	Qrs.	Tons	Cwts.	Qrs.	Tons	Cwts.	Qrs.
Ware .	3	11	0	7	14	0	10	13	0	9	5	3
Seed .		18	0		17	2		15	1		18	0
Chats .		6	1		4	3		8	3		7	1
Total .	4	15	1	8	16	1	11	17	0	10	11	0

It is also shown that this artificial farmyard manure does not lose nitrogen on exposure to weather, while heaps of natural farmyard manure under similar conditions lost as much as 10% to 30%.

The development of practical applications of this kind involves an immense amount of detailed work and a business organisation differing entirely from that of an experimental station. Artificial

farmyard manure has therefore been handed over to a non-profit-making syndicate — the Agricultural Development Company (Pyrford) Ltd., the Chairman of which is Viscount Elveden, M.P., and under these auspices the work is progressing favourably. The results indicate that this is the best method of bringing a new discovery into practical use.

The nature of the gas given off in the fermentation of straw and Nile Sudd (papyrus stems) was studied in the Chemical Department at the request of the Air Ministry. So long as air was present, the gas obtained was carbon dioxide, but when the air supply was cut off methane and hydrogen were obtained in addition. The relative proportions of these two gases depended on the reaction of the medium; if it was kept neutral by means of calcium carbonate there was a considerable quantity of methane along with a certain amount of higher hydrocarbons; if it became acid the total evolution of gas was much diminished and the methane largely disappeared, hydrogen being the chief constituent.

The maximum production of methane was obtained at a temperature of 35°-40° C. and in presence of some nitrogen compound to serve as nutrient to the organisms. In these conditions a yield of 4,400 cubic ft. of gas was obtained per ton of wheat straw, and 9,400 cubic ft. per ton of Nile Sudd; of this gas 38% was carbon dioxide and 62% combustible gas made up of 56 parts of methane and 6 of hydrogen.

The maximum production of hydrogen was obtained when the medium was allowed to become acid, but the total yield of gas was then only 1/30th that given under neutral conditions.

EFFECTS OF MANURES ON THE COMPOSITION AND QUALITY OF CROPS.

Fertilisers affect the habit of growth and the quality of the crop, but the changes, though recognisable by the practical expert, are often so subtle that the chemist is as yet unable to characterise them or to connect them up in any definite way with the chemical composition. In the Rothamsted experiments the practical expert is asked to grade the produce, and his reports are used by the chemist in seeking to trace the chemical relationships. Malting barley and potatoes are being studied in some detail.

MALTING BARLEY.

The experiments are carried out at 13 different centres as part of the Research Scheme of the Institute of Brewing, and full details are given in their Journal. The same seed and the same manurial treatment are adopted at each centre. The yields are given on p. 104. The samples of grain are valued by a committee of expert buyers and are analysed by an experienced brewers' chemist; certain typical samples are separately malted by a maltster. The results will show how quality is affected by manurial treatment, soil and season; in addition, it is hoped from the data thus obtained to deduce chemical relationships which will enable us to express better than at present the value or quality of barley in chemical terms. The experiment began in 1922, one of

the worst seasons in the last 30 years for quality of barley. When the barleys from the different farms are compared, their values are related to nitrogen content; when, however, barleys from different manurial plots on the same farm are compared, the relationship is less marked; it can be shown statistically that the effect is reduced at least one-half (p. 50).

POTATOES.

The relative effects of sulphate of potash, muriate of potash and salt have been studied. The samples were valued by an expert buyer—George Major, Esq., of Major Bros., King's Cross Potato Market.

There was no obvious connection between manuring and valuation. Cooking tests, however, showed certain relationships.

The professional cooking test was kindly carried out by Messrs. Lyons, the well-known caterers, who placed the potatoes in the following order:—

MESSRS. LYONS' COOKING TEST: ORDER OF QUALITY.

1. Sulphate of potash.
2. Muriate of potash.
3. Muriate of potash and salt. No potash.

No farmyard manure was used with this set.

A home cooking test gave the following result:—

1. Sulphate of potash.
2. Muriate of potash and salt.
3. No potash.
4. Muriate of potash.

No dung was given to this set. On the dunged plots the differences were smaller.

It will be observed that both agree in placing the sulphate-treated potatoes at the head of the list, and of the others the only fertiliser as to which there is disagreement is the chloride.

Certain differences were detectable in the laboratory. The tubers receiving sulphate of potash had a higher specific gravity and a larger percentage of dry matter than any others, excepting only those from the no-potash plots receiving dung. The quantities of starch are being determined.

WHEAT.

The wheats grown at one centre—Seale Hayne, Devon—and receiving respectively sulphate of ammonia, muriate of ammonia and no nitrogen, were examined by Dr. Humphries. The two samples grown on muriate of ammonia contained slightly more gluten than those grown on sulphate, but no difference could be detected by the expert buyer or the miller. The baker in one case put the ammonium chloride plot above, and in the other below, the ammonium sulphate plot, but he preferred the unmanured wheat.

THE RELATION BETWEEN QUANTITY OF FERTILISER AND CROP YIELD.

These investigations started from the Broadbalk result that the second increment of nitrogenous fertiliser produced a larger increment of yield than the first. If this proved generally true in farm practice it would mean that under normal conditions of price a farmer would be well-advised to manure pretty liberally. The Broadbalk experiment has, however, certain unpractical features, and a series of field trials under ordinary farm conditions has been carried out.

The results with wheat in 1920 favoured this view (Report 1918-20, p. 79), the yields without nitrogen being 28.9 bushels and with the higher dressing 35.9 bushels per acre. Unfortunately both in 1921 and 1922 the wheat crops were very poor, the yields without nitrogen averaging 17.5 and 13.4 bushels per acre respectively, which values were hardly raised in 1921, and only to 17.1 and 19.7 bushels by the single and double dressing respectively in 1922 (p. 93). No definite conclusion can be drawn from these figures.

Potatoes made much better growth. The tops were not weighed, but the tubers increased in yield with successive increments of sulphate of ammonia, and gave a record crop for this land. The increases for the second increment, however, were not greater than for the first, but probably slightly less; nevertheless under ordinary conditions of price the results would have been very profitable. The figures were :—

GREAT HARPENDEN FIELD: POTATOES, 1922.

(Mean of duplicate set.)

Treatment	Tons per acre	
	Dung (15 tons)	No Dung
Basal manure only : no nitrogen	6.07	5.50
,, ,, plus 1½ cwt. sulphate/ammonia	7.99	7.37
,, ,, plus 3 cwt. sulphate/ammonia	9.73	8.97
,, ,, plus 4½(1) cwt. sulphate/ammonia	10.08	8.98

Basal manure (with dung) equals 4 cwt. super, 1½ cwt. sulphate/potash.
Basal manure (no dung) equals 6 cwt. super, 2 cwt. sulphate/potash.
(1) Of this 4½ cwt., 3 were applied with the seed, and 1½ given later as a top dressing.

These apparent discrepancies are being fully gone into during the coming season.

THE SOIL POPULATION AND THE PRODUCTION OF PLANT FOOD IN THE SOIL.

The important investigations by Mr. Cutler and the staff of the Protozoological Department have necessitated considerable revision of our ideas of the soil population. It had always been supposed that the numbers of organisms present in natural soil

were fairly constant so long as the conditions of temperature, water supply, etc., remained the same. Mr. Cutler's work showed that this is not the case; the protozoa and bacteria vary in numbers from day to day (p. 38), while Mr. Thornton has shown that the bacteria may vary from hour to hour. Careful experiments are being made to see if the production of plant food by the organisms varies in the same way. The changes in numbers of bacteria seem to be brought about by changes in numbers of active amœbæ, but it is not clear why the amœbæ should fluctuate as they do. It does not appear that their variations in numbers are determined primarily by variations in moisture supply or temperature; there seems to be some deep seated biological cause at work.

Besides these hour to hour and day to day variations, there seems to be a seasonal variation in numbers; bacteria, protozoa and, apparently, fungi and algæ, are uplifted in number in Spring and Autumn, but depressed during Summer and Winter. Laboratory experiments have been begun to find an explanation, but the problem is clearly very complex. The depressing effect of protozoa on bacteria in the soil was directly demonstrated by inoculating protozoa and bacteria into sterilised soil; the numbers of the latter were greatly reduced (p. 38). This experiment has often been attempted before, but without success, the experimental difficulties having proved too great. The Bacteriological Department, under Mr. H. G. Thornton, has successfully worked out methods by which the bacteria in the soil can be counted, and their changes in number followed, to a degree of refinement and accuracy that satisfies statistical tests of far greater stringency than had been previously applied (p. 37).

THE CONTROL OF THE SOIL POPULATION.

This work was seriously checked in March, 1921, by the death of Mr. W. B. Randall, who had provided funds for the maintenance of a special assistant. It is, however, being slowly continued. The disappointing results given by certain organic agents which promised well have been traced to their decomposition in the soil. This is in the main bacterial, and a special study has been made by Messrs. Thornton and Gray of the bacteria which break down phenol, cresol and naphthalene. The introduction of certain groups into the molecule retards decomposition and intensifies activity; thus nursery experiments indicate that dichlorcresol is some 25 times as potent for sterilising purposes as ordinary commercial cresol. The large scale experiments are recorded in the report of the Cheshunt Experimental Station.

The effect on the micro-organisms of treating soil with phenol is being studied in the Bacteriological and Protozoological Departments. Three groups of bacteria are found capable of decomposing this substance, belonging respectively to the Mycobacterium, Pseudomonas and Clostridium types; the Mycobacteria are interesting among soil bacteria in that they appear to have a definitely discontinuous geographical distribution; the Pseudomonas organisms are apparently of chief importance in phenol decomposition, as they greatly increase in numbers

when phenol is added to the soil. But there is also an unexpected chemical decomposition which has been studied in the Chemical Department by Mr. Sen Gupta, under Mr. Page; it appears that the small quantity of manganese oxide in the soil plays an important part here.

Serious efforts are also being made to control wart disease of potatoes. Sterilising agents have been found capable of destroying the organisms in a badly infested plot of land so that perfectly clean tubers could be grown; the various problems arising out of the practical application of the method are being studied by Dr. W. B. Brierley, Mr. W. A. Roach and Miss Glynne on plots of land at Ormskirk and at Hatfield.

THE PLANT IN DISEASE.

(ENTOMOLOGICAL, MYCOLOGICAL, INSECTICIDE AND FUNGICIDE DEPARTMENTS.)

Much damage to crops is caused by the attacks of insects and fungi. These pests can often be kept in check by spraying, but on the farm it would usually be cheaper, where possible, to enable the plant itself to resist the attacks. Both methods are being studied.

In the case of one disease—the Wart Disease of Potatoes—certain varieties are absolutely immune. Attempts are being made to find out the reason for this. Immunity might be due to something made in the leaf and distributed throughout the plant, or, on the other hand, it might result from some special characteristic of the lower part of the plant. In order to test these possibilities, Mr. Roach is building up new varieties of potatoes by grafting one sort on to another; he has grafted immunes on to susceptibles and *vice versa*; the resulting plants are then grown in infested soil. So far the substitution of a top from a susceptible plant on to an immune variety has caused no loss of immunity, nor has the substitution of the top from an immune to a susceptible variety conferred immunity. It does not appear, therefore, that immunity is the result of any action in the leaf.

Considerable attention has been paid by Dr. Davidson to the aphids attacking broad beans. It is shown that the rate of multiplication of the insect on the plant differs for the different varieties of bean, though unfortunately the most resistant of the beans has little commercial value. Attempts are therefore being made to breed a variety of high resistance and at the same time having a value to the farmer comparable with that of the present kinds. Even with the same variety, however, the power of resistance is affected by the dissolved substances in the plant tissues, and this can be modified by changes in the nutrients supplied to the plant. In both directions there seem to be possibilities of the control of this troublesome pest.

The usual history of this particular pest is that the asexual forms (which do the damage to the crop) continue throughout the Summer, and are then followed by sexual forms in October which produce eggs that lie dormant through the Winter and hatch out in the following April. Dr. Davidson has, however, shown

that the asexual forms can continue living on beans in a green-house through the Winter and flourish vigorously during the following Summer, thus forming a further source of infestation. This is of importance in certain branches of the glass-house industry.

Mr. J. G. H. Frew has made a study of the biology of the gout fly, and it appears possible that the severity of the attack can be diminished by appropriate manuring. The relation of the time of sowing to the probability of attack is being studied.

Another method of control under investigation in the Entomological Department is through the agency of the natural enemies of injurious insects. Parasites of certain pests—the earwig, pear slug larva, and pear leaf midge—are being bred by Mr. Altson for supply to the New Zealand Government.

The discovery and suppression of winter or alternative hosts is connecting the entomological work with the weed investigations which have for some years been made by Dr. Brenchley in the Botanical Department.

While one hopes for the fullest possible measure of success of these methods of controlling pests, it remains highly probable that control by spraying will always be of great importance. Serious efforts to improve this are therefore being made by Mr. Tattersfield, in conjunction with Dr. Imms and Mr. Morris.

For insect pests the spray fluids may be of two kinds—contact poisons and stomach poisons. Of the latter, arsenic in one or other of its combinations is well known and is quite effective, but unfortunately it is poisonous to man and animals. Of the contact insecticides, nicotine is at present the best, but it is subject to the disadvantages of restricted source of supply and high price. Systematic attempts to find substitutes are steadily yielding results; the method consists in finding the toxicity of an organic compound towards certain test organisms (bean aphis, the larvæ of the common Lackey moth and of *Selenia illumaria*), then preparing derivatives to see which groups and positions tend to the greatest increase in toxicity. The experimental difficulties are great but it is believed that they are now overcome; some of the new substances are sufficiently promising to justify study on the field scale.

Considerable attention has been given by Messrs. Tattersfield and Roach to the extraction of toxic substances from tuba root (*Derris elliptica*), and as the percentage of toxic material in different consignments may vary between 7 and 22, a method of evaluation has been devised (p. 45).

Fungi are controlled by spraying just as insects are, but little is known of the processes involved. Dr. Henderson Smith finds that the number of spores of the fungus (*Botrytis cinerea*) killed by a solution of phenol of given strength, is for short exposures small; for longer exposures it rapidly increases, but there is always a residue of spores that die very slowly. The results are expressible by a sigmoid curve. One practical result is that an experimenter can ascertain the strength of a fungicide which, in the steeping of seed, would cause the maximum injury to the fungus with the minimum injury to the grain.

Heat acts much in the same way as phenol, with the distinction

that there is no delay in action such as is occasioned in the case of fungicides by the slow penetration of the chemical agent.

APICULTURAL INVESTIGATIONS.

The circumstance that Dr. Imms was interested in bees led the Ministry of Agriculture to suggest that the Entomological Department should undertake the study of bees as honey producers, leaving bee diseases to be studied at Aberdeen as at present. Mr. D. M. T. Morland was appointed to be in charge of the work, and he will at an early date proceed to the United States to study the methods in use there. In the meantime, two minor problems of practical importance are being investigated : the suitability of metal combs in place of those naturally built, and the situation of the frames in relation to the hive front.

A field laboratory has been erected and is now in working order.

THE ASSOCIATED FARMS.

WOBURN.

In 1921 the Royal Agricultural Society gave up the Woburn Experimental Farm which they had carried on continuously since 1870, and its two best known fields—Stackyard and Lansome—were in October, 1921, taken over by the Rothamsted Experimental Station so as to ensure the continuance of the permanent wheat and barley experiments which are second only to those of Broadbalk and Hoos fields in point of age. The necessary funds are obtained from a special grant of the Ministry of Agriculture. Dr. Voelcker continues to supervise the experiments as he has done since 1890 ; the continuity of the records is therefore assured. It should be recorded that he acts in an honorary capacity, freely giving much time and trouble to this work. His report will be found on p. 61.

LEADON COURT.

In December, 1922, E. D. Simon, Esq., then Lord Mayor of Manchester, offered us the use of his farm at Leadon Court, Ledbury, for experimental purposes, himself generously defraying the expenses incurred. It was decided to devote the whole farm to a test of the soiling system of keeping dairy cows, which has aroused much interest among farmers. Small scale trials at the Harper Adams Agricultural College had indicated the feasibility of all of the processes involved, but no conclusions as to the economic value of the system could be reached. Mr. J. C. Brown was appointed manager.

The farm is 240 acres in extent, there being at present 110 acres of arable and 140 of grass, of which 20 acres will be ploughed out, making altogether 130 acres of arable and 110 of grass. It is expected to maintain a herd of 100 cows in full milk, and in addition some 30 dry cows, and some 30 young heifers coming on ; also a herd of pigs. It is also hoped to have a considerable amount of wheat for sale.

The scheme of cropping for 1923 is as follows:—

Acreage	Green Food	Expected Yield tons per acre
10	Rye	10
16	Marrow-stem kale	20
8	Mangolds	30
12	Seeds in wheat and pea	10
10	Clover aftermath	5
	Dry Ration	
12	Wheat and pea	3
10	Clover	3
18	Mixtures (beans, peas, wheat, and barley)	$2\frac{1}{2}$
26	Wheat	

The ration per cow will be, from mid-October to the end of May—60lb. green fodder and 15lb. dry fodder (8lb. mixtures and 7lb. hay). For the rest (June to mid-October) the cows will be at grass, aided by forage crops.

On the best pasture the cows are being grazed in rotation, the aim being to secure the advantages of the continental practice of tethering without its disadvantages. They receive also one feed per day of chaffed rye and peas.

LOANS OF LANTERN SLIDES TO LECTURERS.

Lecturers on agricultural science can obtain from the Rothamsted Experimental Station the loan of certain lantern slides free of charge, but on condition that all breakages are replaced.

CO-OPERATION WITH SCHOOLS AND OTHER AGENCIES

Three of the departments have found it advantageous to invite the co-operation of public and elementary schools for the collection of data, and it is satisfactory to record that the scheme has proved successful. In the first instance, a committee of the Science Masters' Association, under the chairmanship of O. H. Latter, Esq., M.A. (Charterhouse School), was formed, and a number of public schools co-operated. Relations have now been secured with practically every type of educational institution: public schools, secondary schools, training colleges, and rural schools. Certain observations on weeds carried out by training colleges and country school teachers are proving very useful to the Botanical Department; other observations of times of flowering, ripening, etc., are of assistance to the Statistical Department in estimating the effect of season on plant growth.

Recently, through the assistance of the Ministry of Education, it has been possible to reach the rural school teachers, and lectures on agricultural science have been given at vacation courses by the Director and members of the staff.

Certain problems in soil physics are best attacked by simple experimental studies of a number of soil types. During the unprecedented drought of 1921 several of the upper science forms of the public schools determined the moisture contents of specified field soils in their district, thus obtaining information required by the Physical Department for its investigations on the water relationships of soils.

DEMONSTRATIONS AND LECTURES TO FARMERS AND STUDENTS.

The appointment of Mr. H. V. Garner as Guide Demonstrator has made it possible for the Station widely to extend facilities for visiting the plots. Farmers and agricultural students are cordially invited to Rothamsted at any time convenient to themselves. May and June are good months for seeing the grass plots, July for the cereals, and September and October for the mangolds and potatoes. In the Winter, Mr. Garner is available for giving lectures on the Rothamsted results to Farmers' Clubs and similar organisations.

PUBLICATIONS DURING THE YEARS 1921-22.

SCIENTIFIC PAPERS.

CROPS AND PLANT GROWTH.

I. WINIFRED E. BRENCHLEY. *"Effect of Weight of Seed upon the Resulting Crop."* Annals of Applied Biology, 1923. Vol. X. pp. 223-240.

Experiments were carried out in water cultures with peas and barley, in which the competitive factors were eliminated as far as possible in order that the results could be more closely correlated with the initial weights of the seeds.

The chief results are as follows :—

1.—There is a steady and considerable rise in the dry weight of the plants as the initial weight of the seed increases. This occurs with both a limited and an abundant food supply.

2.—The efficiency index (rate per cent. increase per day) falls gradually as the weight of the seed rises. With prolonged periods of growth this tends ultimately to counter-balance the initial advantage gained by plants from the heavier seeds, but with annual crops as cereals, roots, peas, etc., harvesting occurs before this equilibrium is reached, leaving the advantage with the heavier seeds.

3.—The relative development of shoot and root is to some extent influenced by the initial weight of the seed, but may vary with the species and with the amount of available food.

4.—The results lend support to the growing agricultural practice of advocating the use of large heavy seed, especially with annual crops. The advantage in the case of perennials would appear to be less, if any, but this has not been determined by laboratory experiments.

II. WINIFRED E. BRENCHLEY, assisted by KHARAK SINGH. *"Effect of High Root Temperature and Excessive Insolation upon Growth."* Annals of Applied Biology, 1922. Vol. IX. pp. 197-209.

When similar water culture experiments are repeated at different seasons of the year and under different environmental conditions, certain variations in result occur which appear to be associated with the temperature of the nutrient solution in which the roots are immersed. Under ordinary environmental conditions of temperature and sunlight the growth of peas, as of barley, is seriously hindered by overcrowding, even when each plant receives a similar supply of food and water. Not only is less dry weight produced, but the pods become thin and distorted, and fail to develop their seeds properly.

Growth tends to be depressed in hot sunny weather when no protection is afforded. The chief detrimental factors concerned appear to be high temperatures at the roots, acting together with strong and prolonged sunshine, though the two factors acting individually are much less harmful. Under these conditions, crowding shelters the roots from overheating and the leaves from too much sunlight, and up to a certain point crowded plants make better growth than those spaced well apart. Overcrowding,

however, still depresses growth, probably because the light and root temperature reductions are too great.

Provided insolation is not excessive, the amount of daily fluctuation of root temperature over a total range of about 22° C. (6.7°—28.9° C.) has comparatively little influence upon growth; high maxima and low minima give similar results to low maxima and relatively high minima, provided the average mean temperatures are not too dissimilar. With high root temperature a difference in the degree of insolation or in the angle of incidence of the sun's rays may have a considerable influence on growth, a slight easing off of the solar conditions enabling much better growth to be made. With very strong sunshine, reduction of high maximum root temperatures (29° C. or above) allows of satisfactory growth when unprotected plants are rapidly killed. The inhibitory action of too high temperatures at the roots is thus clearly shown.

Nevertheless, the growth so made is less good than under more normal conditions of insolation, thus demonstrating the harmful action of too powerful sunlight, when all the root temperatures rule high.

Root temperatures appear to be of greater importance than atmospheric temperatures, as good growth can be made in hot atmospheres, provided the roots are kept relatively cool. There is some reason to believe that the minima are of as much importance as the maxima, *i.e.*, that plants can withstand very high maximum temperatures provided there is a considerable drop to the minima, but cannot put up with the constant conditions of heat induced by fairly high maxima and high minima.

III. Kharak Singh. *"Development of Root System of Wheat in Different Kinds of Soils and with Different Methods of Watering."* Annals of Botany, 1922. Vol. XXXVI. pp. 353-360.

A study of the development of the root system in different kinds of soil and under varying conditions of manuring, watering, and cultivation, is of considerable importance in the Punjab (India), especially where the crops have to depend mainly on artificial irrigation. Duplicate pot experiments were carried out in which wheat plants were grown in various kinds of soil, watering being done on the surface in one case, and in the other through a small porous pot sunk to the level of the soil in the middle of each large pot, thus carrying the water directly to a lower level. The observations were preliminary in nature, but indicate that wheat plants in pots show better growth when watered from below than when watered from above. The difference is greater in light soil in the early stages of growth, but it is more marked in heavy soil in the later stages of growth.

Under the experimental conditions the development of root and shoot was best in pure sand, provided it was supplied with an adequate amount of water and was underlaid by a layer of farmyard manure. The growth of wheat is better in a mixture containing 25 per cent. sand and 75 per cent. Rothamsted soil, than in pure Rothamsted soil, or in a mixture of 50 per cent. sand and 50 per cent. Rothamsted soil. Moreover, wheat plants do not

grow well in brick powder even when underlaid with a layer of farmyard manure.

IV. Violet G. Jackson. *"Anatomical Structure of the Roots of Barley."* Annals of Botany, 1922. Vol. XXXVI. pp. 21-39.

The root system of a well-developed barley plant, whether grown in soil or water culture, consists of two types of roots : (*a*) a thin branched type, and (*b*) a thick "unbranched" type, with very abundant root hairs. The present paper embodies the results obtained from an anatomical investigation of the two types.

A branched root possesses a much thickened stele with a single large axile vessel and six to eight xylem groups, all bounded by a very thick-walled endodermis. In an "unbranched" root neither the endodermis nor the stelar tissues are thickened, the xylem groups number from twelve to sixteen, and the middle of the root consists of thin-walled pith cells traversed by four to six ducts.

The chief function of the "unbranched" roots is probably to provide the plant with a plentiful supply of water and its dissolved food, at the time when vigorous growth is setting in. This function is provided for by :—

(*a*) Abundant root hairs ;
(*b*) An increased number of large vessels and central ducts ;
(*c*) The existence of a stele composed almost entirely of thin-walled elements.

This view receives support from the fact that these roots are formed only during the early stages of the plant's vigorous growth. Researches on the development of root and shoot showed that the formation of "unbranched" roots had entirely ceased by time the plant had finished its vegetative growth and was entering on its reproductive phase. At this period of the plant's history, the nitrogen and ash constituents are migrating steadily from the straw into the grain, so that there is no need for a large root-absorbing area. On the other hand, if the "unbranched" roots functioned chiefly as buttress-roots, the plant would need them even more when the heavy grain is being formed ; but that is just the time when their development ceases. Therefore the most probable function for the "unbranched" roots is to ensure a good supply of water, etc., when the plant is in a condition of strong vegetative growth.

V. Katherine Warington. *"The Effect of Boric Acid and Borax on the Broad Bean and certain other Plants."* Annals of Botany, 1923. Vol. XXXVII. pp. 1-44.

Boron appears to have some special function in the nutrition and development of the broad bean, as this plant fails to grow satisfactorily in nutritive solution from which boron is withheld. The results of the experimental work are:—

1.—In water culture a continual supply of boric acid appears to be essential to the healthy growth of the broad bean plant, concentrations of one part of boric acid (H_3BO_3) in 12,500,000 parts—25,000 parts of nutrient solution being beneficial.

In its absence, death occurs in a characteristic manner, the apex of the shoot becoming withered and blackened. The addition of boric acid after these symptoms have set in, but before

death finally occurs, results in a renewal of growth by means of new lateral shoots and roots. This type of dying has not been observed in broad bean plants grown in pot culture, and it is concluded that sufficient boron is present, as a trace has been detected in the soils used.

2.—The absence of boron does not cause death in barley, growth being healthy in ordinary culture solution.

3.—Excess of boric acid is poisonous to the broad bean, injury being apparent with one part of boric acid (H_3BO_3) in 5,000 parts of the water culture medium and with 0.5 gm. or 1.0 gm. per 22½ lbs. of soil in pot culture, according to the method of application.

4.—Boric acid is more poisonous to barley than to the broad bean; in water culture a concentration of one part of H_3BO_3 in 2,500,000 parts of nutrient solution, and in pot culture .5 gm. per 22½ lbs. of soil is injurious. Smaller quantities are either ineffective or slightly favourable, though the benefit is usually evident to the eye only and not shown in the dry weight.

5.—Injury is marked by (i.) retardation of germination, (ii.) first chlorosis and later brown markings of the leaves; the barley leaf becomes spotted but that of the broad bean shows a band of brown along the margins. (iii.) Retardation in maturing in the case of barley in soil culture.

6.—Preliminary experiments show that several other plants, and especially *Phaseolus multiflorus* and *Trifolium incarnatum,* appear to benefit from the addition of small quantities of boric acid to the nutrient solution, though rye, like barley, is apparently indifferent to low concentrations.

7.—Boron is found to be present in considerable quantity in the dried shoots of the broad bean plants grown in a nutrient solution containing no boron, and also in the seed. In garden-grown plants a larger proportion of boron was present in the pods than in either the stems or leaves. No more than a trace was detected in the barley seed or in the dried shoots of untreated barley grown in water culture.

8.—It is suggested that the function of boron in the case of the broad bean is probably nutritive rather than catalytic, since a supply is required throughout the life of the plant. A parallel is drawn between the action of boron on plants and the vitamines on animal life.

VI. KATHERINE WARINGTON. *"The Influence of Manuring on the Weed Flora of Arable Land."* Journal of Ecology, 1924. Vol. XII.

Examinations have been made of the weed species present on the variously manured plots of fields which have been cropped continuously for a considerable period with :—

1. Winter wheat (Broadbalk Field).
2. Spring barley (Hoos Field).
3. Mangolds (Barn Field).

The data show that the chief factors which determine the dominant species are the crop and the methods of cultivation, the most important weeds being quite different in the three fields. Winter fallowing has a particularly striking influence on the weed flora.

However, in the event of any serious deficiency such as an inadequate nitrogen supply, or a prolonged application of ammonium salts only, the influence of the manurial treatment becomes the most important factor and the flora undergoes modification of a similar nature irrespective of the methods of cultivation. In such cases a perennial type of weed, as *Equisetum arvense, Tussilago farfara* or *Cirsium arvense*, was invariably found to predominate.

Comparisons are between with the weeds recorded in 1867 on Broadbalk and Hoos fields and those found at the present day. Considerable reduction in the number of species has taken place in the former case, while changes in the individuals comprising the flora have occurred on both fields.

The distribution and relative abundance of species and individuals are also described in the case of Broadbalk field.

METHODS OF STATISTICAL EXAMINATION AND RESULTS.

STATISTICAL TREATMENT OF SMALL SAMPLES.

VII. R. A. Fisher. *"On the 'Probable Error' of a Coefficient of Correlation deduced from a small Sample."* Metron, 1921. Vol. I., No. 4. pp. 1-32.

Agricultural experiments deal almost invariably with a number of replicated plots, or parallel experiments, which is statistically small; approximate methods suitable for large samples are therefore liable to break down, and to lead to erroneous conclusions. This paper gives the exact form of distribution for correlation coefficients obtained from small samples. By changing the scale upon which the correlation is measured, correlations from small samples may be treated with accuracy, and at the same time corrected for the small bias which is introduced by the standard methods of calculation.

AGREEMENT OF THEORY AND OBSERVATION.

VIII. R. A. Fisher. *"On the Interpretation of χ^2, from Contingency Tables, and the Calculation of P."* Journal of the Royal Statistical Society, 1922. Vol. LXXXV. pp. 87-94.

Statistical tests of the agreement of series of experimental observations with any hypothesis, by which it is intended to interpret them, may be carried out by calculating the statistic χ^2, which measures the discrepancy. The distribution of χ^2, when the hypothesis tested is in fact true, can be calculated, and in this manner cases in which the discrepancy is excessive may be detected. In this paper it is shown that when the data to be tested have been used to construct the hypothetical expectation it is necessary to adopt a more severe test of agreement than that previously in use. This change of procedure, which particularly affects tests of independence in contingency tables, and of the goodness of fit of theoretical curves, may be simply and accurately effected by taking account of the number of degrees of freedom in which observations may differ from expectation, instead of merely the number of frequency classes.

THEORY OF STATISTICAL REDUCTIONS.

IX. R. A. FISHER. *"On the Mathematical Foundations of Theoretical Statistics."* Philosophical Transactions of the Royal Society, 1922. Vol. CCXXII. pp. 309-368.

The main desideratum in the statistical reduction of data is that the statistics calculated shall include the whole of the information supplied by the data. It has been possible to put this requirement in a mathematical form, and so to lay down general conditions for the complete exhaustion of the data; in particular it is possible to ascertain for any special statistical method proposed, of what percentage of the total information available it makes use. Many such tests are applied to current statistical methods, and in particular to the estimation of the numbers of soil protozoa by the dilution method.

RAINFALL IN BRITAIN.

X. R. A. FISHER and W. A. MACKENZIE. *"The Correlation of Weekly Rainfall."* Quarterly Journal of the Royal Meteorological Society, 1922. Vol. XLVIII. pp. 234-242.

To study the effects of weather on crop production by means of simultaneous crop and weather records from different parts of the country, and thereby to reduce the number of years required for the accumulation of data comparable with the existing Rothamsted records, it is necessary to know the correlation between the meteorological records of different stations. Such information is also necessary in repairing defective records from those of neighbouring stations, as also in estimating weather conditions over local areas, such as river basins. This paper is a study of records from Aberdeen, York, and Rothamsted in respect of weekly rainfall. Even Rothamsted and Aberdeen 375 miles apart show a distinct positive correlation (average value .3717) in rainfall; the intermediate station, York, 150 miles from Rothamsted, and 225 miles from Aberdeen, gives average correlations .5898 and .5275. All three comparisons show well marked annual oscillations, the rainfall being most uniform in winter and least so in the early summer. Meteorologists suggest two possible causes for this novel phenomenon: (i.) the summer prevalence of local thunderstorms, (ii.) the more northern track of the summer cyclones. Whatever its cause, it is apparent that simultaneous crop and weather observations will throw light especially on the effects of summer rain or drought.

PREDICTION FORMULÆ.

XI. R. A. FISHER. *"The Goodness of Fit of Regression Formula and the Distribution of Regression Co-efficients."* Journal of the Royal Statistical Society, 1922. Vol. LXXXV. pp. 597-612.

Statistical predictions are based upon regression formulæ, and their importance required that the correction established in Paper No. VIII. (see above) should be applied in detail to such cases. It

was possible to find the exact distribution of the discrepancy between prediction and observation, and to render previous methods more exact in other points besides that mentioned above. In addition the true form of the distribution of the regression coefficients was established, for which approximate forms only had been previously available.

INHERITANCE CORRELATIONS.

XII. R. A. FISHER. *"On the Dominance Ratio."* Proceedings of the Royal Society of Edinburgh, 1922. Vol. XLII. pp. 321-341.

The effects of selection on the inheritance correlations show themselves in the dominance ratio. The value obtained from human measurements are all close to $\frac{1}{3}$, and this value is not readily intelligible upon the simpler theory in which the effects of selection are ignored. When selection is taken into account it is demonstrated that the dominance ration will rise to $\frac{1}{3}$, thus providing the final step necessary to bring the whole of the existing correlation measurements in mankind into harmony with the Mendelian theory of inheritance.

CROSSOVER RATIOS.

XIII. R. A. FISHER. *"The Systematic Location of Genes by means of Crossover Observations."* American Naturalist, 1922. Vol. LVI. pp. 406-411.

It is shown how the whole of the information supplied by crossover observations may be utilised in determining a consistent system of crossover ratios; the method is based upon that developed in Paper No. IX. (see above), and the working is analogous to that of a solution of least squares.

ACCURACY OF BACTERIAL COUNTING.

XIV. R. A. FISHER, H. G. THORNTON, and W. A. MACKENZIE. *"The Accuracy of the Plating Method of Estimating the Density of Bacterial Populations."* Annals of Applied Biology, 1922. Vol. IX. pp. 325-359.

As a rule, the accuracy of biometrical determinations must be ascertained empirically from a statistical study of the observations; in certain cases, as has been shown in the theory of hæmocytometer counts, the law of variation may be calculated, and the accuracy known with precision, provided the technique of the counting process is effectively perfect. A study of the extensive bacterial count data accumulated at Rothamsted by Cutler and Thornton, using Thornton's agar medium, indicated that the same law of variation, the Poisson series, was obeyed by the number of colonies counted on parallel plates. Statistical tests were devised which proved that, save for a small proportion of definite exceptions, the necessary perfection of technique was effectively realised. In studying the exceptional cases it appeared that these fall into two classes: (i.) an abnormally high variation which, when investigated experimentally, has been traced to certain bottom spreading organisms isolated from soil from Leeds and from Rothamsted,

and (ii.) an abnormally low variation ascribable to defective procedure in the preparation of the medium. Application of the same tests to other extensive series of bacterial counts showed that a similar approach to theoretical accuracy, though rare, had been obtained by Breed and Stocking in counts of *B. coli* in milk. It should be emphasised that all cases of departure from the theoretical law of distribution, which have been investigated, are associated with large systematic errors in the counts; for this reason simple tests are presented by which such deviations from the theoretical accuracy of the method can be detected.

ACCURACY OF APHIS COUNTS.

XV. R. A. FISHER. *"Appendix to 'Biological Studies of* APHIS RUMICIS,' *by* J. DAVIDSON." Annals of Applied Biology, 1922. Vol. IX. pp. 142-145.

A special method was developed for determining the accuracy of Dr. Davidson's counts on Aphids; by this means it was possible to show that the 19 varieties of bean tested could be assigned to only six degrees of susceptibility to aphis infestation.

MANURIAL RESPONSE OF POTATO VARIETIES.

XVI. R. A. FISHER and W. A. MACKENZIE. *"The Manurial Response of Potato Varieties."* Journal of Agricultural Science, 1923. Vol. XIII. pp. 311-320.

In an experiment carried out at Rothamsted (1922), twelve potato varieties were each tested with six different manurial treatments, each test being triplicated. Consequently it was possible to test a question upon which very little information has hitherto been available, namely, whether different varieties respond alike to manurial treatment. It is impossible to generalise from a single test of a single species, and it has seemed to the authors of more importance to call attention to (i.) the kind of data required for such an enquiry, and (ii.) the type of statistical treatment needed to elicit an answer, than to emphasise the fact that no significant differences are observable in the manurial response, although the varieties differed much among themselves in yield, and the different treatments also resulted in large differences in yield.

SOIL ORGANISMS.

XVII. E. J. RUSSELL. *"Les Micro-Organismes du Sol dans leurs rapports avec la croissance des plantes. Position actuelle du probléme."* Ann. de la Sci. Agronomique, 1921. pp. 49-67.

A review of the present position of our knowledge on this subject.

ALGÆ.

XVIII. B. MURIEL BRISTOL and HAROLD J. PAGE. *"A Critical Enquiry into the Alleged Fixation of Atmospheric Nitrogen."* Annals of Applied Biology, 1923. Vol. X. pp. 1-30.

Four species of green algæ were grown in pure culture on six media which had as a common basis a solution of mineral salts devised by Schramm, but differing in that the nitrogen was supplied as ammonium nitrate, calcium nitrate or ammonium sulphate; for each of these sources of nitrogen there were two media, one without added sugar and the other containing 1% glucose. The cultures were aerated daily with sterile air free from combined nitrogen. The initial nitrogen-content of the medium in each flask was ascertained from check analyses of that medium, and the nitrogen-content after six months' growth was determined by chemical analysis of the whole of the contents of the flask.

In practically all cases a good growth of algæ was obtained, and in a large number the growth was luxuriant. Nevertheless the analytical results afforded no evidence whatever that any fixation had occurred. In fact, those cultures the growth of which had been most luxuriant had a final nitrogen-content that was, if anything, slightly lower than that of the medium originally.

This result differs from that obtained by Wann (Amer. Jour. Bot., 1921., Vol. VIII.) Investigation showed, however, that the method by which he estimated nitrogen breaks down in presence of nitrate. The results give the appearance of nitrogen fixation even when none occurred.

The chemical methods used by the present authors were free from these sources of error and, as already stated, no fixation could be detected. While it is quite conceivable that green algæ might under certain conditions, as yet unknown, assimilate atmospheric nitrogen, there is so far no trustworthy evidence that they can do so.

BACTERIA.

XIX. H. G. Thornton. *"On the Development of a Standardised Agar Medium for Counting Soil Bacteria, with especial regard to the Repression of Spreading Colonies."* Annals of Applied Biology, 1922. Vol. IX. pp. 241-274.

For counting bacteria by the plating method it is a first essential to accuracy that the plating medium should give uniform results. The medium should be exactly reproducible, *i.e.*, different batches should give similar results. In the medium here developed, this has been achieved by using pure chemical compounds as food constituents, selecting those compounds that did not alter the reaction of the medium during sterilisation.

Further parallel platings of a suspension of organisms made on a single batch of medium should develop the same number of colonies (within the limits of random sampling variance). This necessitates the independent development of each colony on the plate, which on agar media is frequently prevented by the development of bacteria that form rapidly spreading colonies which interfere with the development of other bacteria.

A special study was therefore made of a common "spreading" organism with a view to limiting its growth. It was found that the organism spreads over the agar surface by active motility and that the factors controlling its spread were (i.) the existence of a

surface film of water on the agar, and (ii.) the rate of multiplication previous to the drying of this film. In the present medium this rate of multiplication has been much reduced so that spreading colonies are greatly restricted. The medium has the following composition :—K_2HPO_4, 1.0 gram; $MgSO_4$, 7 H_2O, 0.2 grs.; $CaCl_2$, 0.1 gr.; NaCl, 0.1 gr.; $FeCl_3$, .002 grs.; KNO_3, 0.5 grs. Asparagine, 0.5 grs.; mannitol, 1.0 gram; agar, 15.0 grs.; water to 1000 cc. Reaction brought to PH 7.4 before sterilisation.

(For the rigid test of this medium, see Paper XIV., p. 35.)

PROTOZOA.

XX. D. W. CUTLER, LETTICE M. CRUMP, and H. SANDON. *"A Quantitative Investigation of the Bacterial and Protozoan Population of the Soil."* Phil. Trans. Roy. Soc., London, B., 1922. Vol. CCXI. pp. 317-350.

The results of 365 consecutive daily counts of the numbers of bacteria and of six species of protozoa in a normal field soil are given, and the methods of counting bacteria and protozoa are described.

The numbers of both bacteria and protozoa rarely remain the same from one day to the next. The fluctuations are very great, but it has not been found possible to connect them with meteorological or general soil conditions.

Fourteen-day averages of the daily numbers demonstrate that well-marked seasonal changes in the soil population are superimposed on the daily variations in numbers. In general, both bacteria and protozoa are most numerous at the end of November and fewest in February. These changes are not directly influenced by temperature or rainfall, but show a similarity to the seasonal fluctuations recorded for many acquatic organisms.

There is a slight tendency for the various species of flagellates to fluctuate together from day to day, but this is not shown by the two species of amœbæ.

An inverse relationship is found between the numbers of bacteria and active amœbæ in 86% of the total observations.

A two-day periodicity obtains for the active numbers of one species of flagellate (*Oicomonas termo*).

XXI. D. W. CUTLER. *"The Action of Protozoa on Bacteria when Inoculated into Sterile Soil."* Annals of Applied Biology, 1923. Vol. X. pp. 137-141.

Soil sterilized by heat was inoculated with :—

(*a*) Bacteria alone;
(*b*) ,, + one species of amœba;
(*c*) ,, + one species of flagellate.

Daily bacterial counts made on each portion of soil showed that the one containing no protozoa sustained a greater number of bacteria than those containing protozoa. Also the bacteria in the protozoa free soil did not exhibit the fluctuations in numbers characteristic of soil in which protozoa were living.

XXII. S. M. NASIR. *"Some Preliminary Investigations on the Relationship of Protozoa to Soil Fertility with Special Reference to Nitrogen Fixation."* Annals of Applied Biology, 1923. Vol. X. pp. 122-133.

A perusal of the results shows that the presence of protozoa has no depressing effect on the nitrogen-fixing bacteria, either in the artificial culture media, or in sand cultures. From a total of 36 experiments done in duplicates or triplicates, 31 showed a decided gain, while only 5 gave negative results. The average figure for fixation works out to be 8.5%, which is well above the experimental error.

The highest fixation of 36.04% was recorded in sand cultures in the case of ciliates. All the three types of protozoa gave higher fixation figures. The experiment was repeated six times, and every time concordant results were obtained.

XXIII. D. W. CUTLER and LETTICE M. CRUMP. *"The Rate of Reproduction in Artificial Culture of Colpidium Colpoda."* Biochemical Journal, 1923. Vol. XVII. pp. 174-186.

Methods are given by which it has been found possible to obtain comparable results when studying the reproductive rates of certain protozoa in mass cultures.

It is shown that within a relatively short period after inoculation, under certain conditions, a varying proportion of the organisms die; and that this is correlated with the age of the culture from which the inoculation was made.

By means of three hourly counts it was found that death occurs even during the period of maximum reproduction.

Evidence is supplied that in certain strains of Colpidium the rate of reproduction from inoculation to the maximum numbers attained is constant.

XXIV. MADELEINE PEREY. *"Les Protozoaires du Sol."* Ann. Sci. Agron., 1923. Vol. LXIII. pp. 333-352.

A short review is given of our knowledge of soil protozoa together with an account of the species of protozoa found in certain French soils.

XXV. H. SANDON. *"Some Protozoa from the Soils and Mosses of Spitsbergen."* Journ. Linn. Soc., 1923. Vol. XXXIV.

Samples of soils and mosses brought back from Spitsbergen by the Oxford University expedition of 1921 and 1922 were examined, and an abundant protozoal fauna, practically identical with that found in soils and mosses of temperate lands, was found. Protozoa were found to be considerably more numerous in some of the soil samples than in others, but no close connection could be found between the numbers of species present and the physical or chemical properties of the soils. Descriptions are given of seven previously undescribed flagellates, of which five, however, occur also in Rothamsted soils.

FACTORS DETERMINING ENVIRONMENTAL CONDITIONS.

XXVI. E. J. Russell. *"The Physico-Chemical Problems relating to the Soil."* Trans. Faraday Society, 1922. Vol. XVII. pp. 219-223.

A general survey of the physico-chemical factors operating in the soil and their influence on fertility. The soil is regarded as a system formed of four components : (i.) mineral particles ; being disintegrated and decomposed rock fragments which, through the action of weather, water, ice and other factors, have in course of time been reduced to dimensions varying from about 1 mm. in diameter to molecular orders of magnitude. (ii.) Colloidal material ; either very fine particles or a jelly coating the larger particles and consisting of materials such as precipitated oxides of iron and aluminium, silicia, etc., or both. (iii.) Intermingled in most intimate fashion with this is the organic matter, residues of past generations of plants and animals, which represents the source of energy for the large population of soil organisms. (iv.) The soil solution, being the soil water and everything dissolved therein. The whole mass is permeated with air. It is shown that the agricultural and physical properties of the soil can to a considerable extent be explained by such a system, but there are facts which do not as yet readily fit it.

A more detailed discussion of certain aspects of the subject is given in the following three papers.

XXVII. H. J. Page. *"The Part Played by Organic Matter in the Soil System."* Trans. Faraday Society, 1922. Vol. XVII. pp. 272-287.

The influence of the humic material of the soil, on the physical and physico-chemical properties of the soil is discussed. Owing to the colloidal nature of this humic material, its chemical nature and mode of formation are still little understood. The established agricultural practice of using dung, green manures, etc., to maintain the fertility of the soil, however, depends in a large degree on the colloidal nature of the humic material derived from such organic manures ; even without more knowledge of the chemical nature of humus, its effect on tilth, moisture relationships, supply of plant nutrients, and soil reaction can be explained, at any rate on broad lines, in terms of its physical, *i.e.,* colloidal, properties.

XXVIII. B. A. Keen. *"The System Soil—Soil Moisture."* Trans. Faraday Society, 1922. Vol. XVII. pp. 228-243.

A general discussion of the relations existing between the soil and its moisture content, with especial reference to the physical significance of the various divisions of soil moisture that have been proposed from time to time.

XXIX. E. M. Crowther. *"Soil Acidity in its Physico-Chemical Aspects."* Trans. Faraday Society, 1922. Vol. XVII. pp. 317-320.

A general discussion of the methods used for the determination of the acidity and lime requirements of soils, with especial reference to the hydrogen-ion concentration of soil suspensions and the action of neutral salts on acid soils.

XXX. W. B. HAINES. *"The Volume-Changes Associated with Variations of Water Content in Soil."* Journal of Agricultural Science, 1923. Vol. XIII. pp. 296-310.

A new and simple method of measuring the shrinkage of moist soil on drying is described, which at the same time gives values for the pore space and specific gravity of the soil. Diagrams are given showing the characteristics of the shrinkage for diverse samples, including pure clay, heavy loam, sandy and peaty soils. The shrinkage is shown to take place in two stages, in both of which there is a linear relationship to the moisture content. The first stage is largely governed by the clay-content of the soil and its limit is fixed by the point at which air begins to replace water in the pores of the soil. The second stage, called the residual shrinkage, is smaller than the first, and seems to depend upon the more highly colloidal material which has been supposed to surround the clay and other particles. Explanation of the shrinkage is developed on these lines with confirmatory experiments.

The effect of alternate wetting and drying of soil in producing a good tilth is illustrated.

XXXI. B. A. KEEN and H. RACZKOWSKI. *"The Relation between the Clay Content and Certain Physical Properties of a Soil."* Journal of Agricultural Science, 1921. Vol. XI. pp. 441-449.

A simple experimental method has been described for measuring certain physical constants of soil, using small brass boxes into which soil passing a sieve of 100 meshes to the inch has been packed by hand. The quantities determined are :—

1. The weight of unit volume (1100 ccs.) of air-dry soil, or the apparent specific gravity.
2. Amount of water taken up by unit weight of soil.
3. Pore space.
4. Specific gravity of the soil.
5. The volume expansion of unit volume (100 cc.) of soil when saturated.

The results for one soil only are given, and discussed, to illustrate the method. With the co-operation of the Science Masters' Association it is being applied to a number of soils by various schools.

The particular soil used was obtained in six depths, as follows : 0-6″, 6-12″, 12-18″, 2-3′, 3-4′, and the constants were determined in each depth. It was shown that 1 and 4 varied inversely with the percentage of clay in the soil, while 2, 3, and 5 varied directly with the clay percentages. The effect on the constants of the larger quantities of organic matter present in the top two layers of soil was, weight for weight, approximately equal to that of the clay, except in the volume expansion results where the effect, if any, was within experimental error.

It is possible that the fraction fine silt II., whose upper limit of diameter is .005 mm., has similar effects to the clay fraction.

XXXII. B. A. Keen. *"Evaporation of Water from Soil II. Influence of Soil Type and Manurial Treatment."* Journal of Agricultural Science, 1921. Vol. XI. pp. 432-440.

Further experiments have been done on the evaporation of water from soil, using the same apparatus and technique as described in an earlier paper. The present series of experiments was designed to investigate the effect of clay content and manurial treatment on the evaporation. Two soils have been used, one containing only 6% clay and the other 15%, and from each soil samples were taken from plots which had received (*a*) no manure, (*b*) artificial manure, (*c*) farmyard manure. The rate at which the soils lost water over concentrated sulphuric acid and at a constant temperature was found to depend firstly on the amount of clay present, and secondly on the amount of organic material in the soil. The differences due to content of organic material were more obvious in the soil containing the larger amount of clay; the farmyard manure plot lost water at the slowest rate, and the unmanured plot occupied an intermediate position. In the sandy soil the differences in evaporation due to manuring were small.

There is evidence that the moisture equivalent of these soils measures the percentage of water at which the evaporation is first directly affected by the soil particles, and that at percentages of water in excess of the moisture equivalent evaporation is taking place substantially from a free water surface.

XXXIII. E. J. Russell and B. A. Keen. *"The Effect of Chalk on the Cultivation of Heavy Land."* Journal of Ministry of Agriculture, 1922. Vol. XXVIII. pp. 419-422.

Measurements taken with a dynamometer showed that dressings of chalk applied 8 years ago were still effective in facilitating cultivation, the saving of drawbar pull being in these trials no less than 180 lb. on a three furrow plough (see p. 12).

THE PLANT IN DISEASE.

INSECT PESTS AND THEIR CONTROL.

XXXIV. A. D. Imms. *"Recent Research on the Head and Mouth-parts of Diptera."* Entomologist's Monthly Magazine. 3rd Series, 1920. Vol. VI. pp. 106-109.

A short discussion of the subject from the morphological standpoint.

XXXV. J. Davidson. *"Biological Studies of* Aphis Rumicis *Linn. IV. Reproduction on varieties of* Vicia Faba*—with a Statistical Appendix by* R. A. Fisher." (See No. XV.) Annals of Applied Biology, 1922. Vol. IX. pp. 135-145.

The reproduction of the bean aphis on 18 varieties of field beans was tested and compared with reproduction on Prolific Longpod broad beans.

The mean values of infestation for the varieties ranged from 37 to 1,037.

These values allow of the varieties being tentatively grouped into classes representing various degrees of susceptibility ranging from 98% to 3%. The results obtained indicate that resistance or susceptibility may be largely determined by genetic factors in the plant.

XXXVI. J. DAVIDSON. *"Biological Studies of* APHIS RUMICIS *Linn. V. The Penetration of Plant Tissues and the Source of the Food Supply of Aphids."* Annals of Applied Biology, 1923. Vol. X. pp. 35-54.

The food of aphids is the juices of plants which they obtain by penetrating the tissues by means of a delicate piercing organ formed by four chitinous stylets.

The piercing organ passes between the cortical cells—occasionally through individual cells—to the vascular bundles.

The saliva secreted by the aphis acts on the middle lamella of the cell wall. It also causes plasmolysis of the cells; and it is able to convert starch into sugar.

The phlœm tissue is the chief source of the food supply, but other cells of the plant, such as cortex and mesophyll, may be tapped for nourishment.

The sucking out process is usually intracellular, although intercellular suction sometimes goes on.

The varying physiological constitution of different plants or even varieties of the same species of plant is important in relation to the biology and physiology of aphids.

The composition of "honey dew"—the sugary excrement of aphids—is in close relationship with the particular species of plant and aphids concerned.

XXXVII. H. M. MORRIS. *"The Larval and Pupal Stages of the* BIBIONIDÆ. *Part I."* Bull. Entom. Research, 1921. Vol. XII. pp. 221-232.

Deals chiefly with the biology and metamorphosis of *Bibio marci* whose larvæ infest grass-land and have been reported to injure various crops.

XXXVIII. H. M. MORRIS. *"On the Larva and Pupa of a Parasitic Phorid Fly*—HYPOCERA INCRASSATA MEIG.*"* Parasitology, 1922. Vol. XIV. pp. 70-74.

Deals with the biology of a species not hitherto investigated, which parasitizes larvæ of *Bibio marci.*

XXXIX. H. M. MORRIS. *"The Larval and Pupal Stages of the* BIBIONIDÆ. *Part II."* Bull. Entom. Research, 1922. Vol. XIII. pp. 189-195.

An investigation of the biology and metamorphosis of DILOPHUS FIBRILIS and D. ALBIPENNIS, the former species being recorded as injuring the roots of various plants.

XL. H. M. Morris. *"On a Method of Separating Insects and other Arthropods from Soil."* Bull. Entom. Research, 1922. Vol. XIII. pp. 197-200.

Describes an apparatus consisting of a galvanized framework supporting a graduated series of sieves, which enables arthropods to be separated from soil by means of a current of water.

XLI. H. M. Morris. *"The Insect and other Invertebrate Fauna of Arable Land at Rothamsted."* Annals of Applied Biology, 1922. Vol. IX. pp. 281-305.

A detailed study of the soil fauna of Broadbalk field, involving a comparison of the invertebrata of plots 2 (dunged) and 3 (unmanured), their distribution in depth, and relative numbers. The main conclusions are that the bulk of the fauna is concentrated in the first three inches of the soil, and that there are on an average 15,000,000 invertebrates per acre in plot 2 (receiving farmyard manure annually) and 5,000,000 in plot 3 (unmanured since 1839). The dominant organisms are insects which numbered over 7,700,000 in plot 2 and about 2,500,000 in plot 3. The total amount of the nitrogen contained in these organisms works out at 7349.6 gm. (16.2 lbs.) per acre in plot 2 and 3409.2 gm. (7.5 lbs.) per acre in plot 3. It is unlikely that there is any appreciable loss of this nitrogen from the soil. The observations show that although the introduction of farmyard manure greatly increases the invertebrate population of the soil, the organisms which exhibit increased numbers are saprophagons and not directly injurious to the growing crop.

XLII. J. G. H. Frew. *"On the Morphology of the Head Capsule and Mouth-parts of* Chlorops Tæniopus Meig. (*Diptera*)." Journal Linn. Society, 1923.

The head capsule is described and some modifications suggested of the homology of its facial aspect in Cyclorrhapha as put forward by Peterson in 1916.

The following conclusions are arrived at :—

The dorsal and lateral borders of the oval depression mark the position of the arms of the epicranial sature.

All regions of the head dorsal and lateral to the oval depression are derived from the paired sclerites of the head and the frons and clypeus lie within the depression.

The antennæ arise on the vertex.

The superficial plate of the fulcrum is the clypeus or fronto-clypeus.

The tormæ are the chitinised plates joining the sides of the clypeus to the sides of the basipharynx.

XLIII. J. C. F. Fryer, R. Stenton, F. Tattersfield, and W. A. Roach. *"A Quantitative Study of the Insecticidal Properties of* Derris Elliptica (*Tuba Root*)." Annals of Applied Biology, 1923. Vol. X. pp. 18-34.

Extracts of *Derris elliptica* are shown to have a high insecticidal value, particularly for caterpillars. They are not so toxic to aphids.

The principles of the root toxic to insects are the white crystalline derivative, usually called "tubatoxin," and a resin of a golden yellow colour identical with the "derride" of Sillevoldt.

The dry root itself may be used in a finely powdered condition worked up with water together with soap or other emulsifying reagents.

As the pure poisons found in derris root are solids and only slightly soluble in water, their toxicity appears to depend upon their degree of dispersion.

A biological method of determining insecticidal properties quantitatively is described. It depends on dipping insects for a constant period of time in known strengths of highly dispersed emulsions or suspensoids in dilute aqueous solutions of saponin. Results agreeing with those given by the chemical method described below were obtained, and it enabled a comparison to be made between extracts of derris and nicotine. To certain caterpillars, tubatoxin and derride are shown to be of the same order of toxicity as nicotine.

XLIV. F. Tattersfield and W. A. Roach. *"The Chemical Properties of* Derris Elliptica *(Tuba Root)."* Annals of Applied Biology, 1923. Vol. X. pp. 1-17.

The toxic principles of *Derris elliptica* have been isolated and some of the more simple properties examined. A chemical method for evaluating the root has been outlined and a suitable extraction apparatus described.

The most important constituents of the root are a white crystalline derivative, usually called "tubatoxin," and a resin or a series of resins identical with the "derride" of Sillevoldt and the "tubain" of Wray. Besides these two, yellow crystalline derivatives and a liquid resin were isolated.

"Tubatoxin," the yellow crystalline derivatives, and the resins contain methoxyl groups and these compounds appear to be interrelated. "Tubatoxin" by exposure to light, and by prolonged boiling with organic solvents, is converted into three yellow crystalline products and a resin. This suggests that the "anhydroderride" of Sillevoldt may have been formed during the process of extraction and may not exist as such in the root.

The poisons from the root are readily extracted by means of organic solvents. Ninety-five per cent. alcohol extracts them together with non-toxic derivatives. Benzene, dry ether, carbon tetrachloride are also good solvents for extraction purposes and have a selective dissolving action on the poisons. Petroleum derivatives are not suitable for complete extraction. Prolonged boiling with solvents may cause some loss of toxicity in the extracts owing to chemical change in the "tubatoxin." For economic purposes, benzene and its congeners, or alcohol, are probably the most suitable extraction reagents, provided the temperature of extraction is not allowed to rise too high.

The root may be evaluated by chemical means by extracting the dry root with dry ether, and the genuineness of the extracts confirmed by the determination of the methoxyl content by the Zeisel method. Extracts from different deliveries varied between

7 and 22 per cent., and the content of CH_3O in the extracts between 13.5 and 14.7 per cent. A qualitative test for "tubatoxin," devised by Dr. Durham, is outlined.

The amounts of the non-toxic constituents vary widely in different consignments. They seem to have some value as emulsifying and wetting agents. As the root, however, arrives in this country in a dry state, in which the constituents have probably coalesced, the use of foreign emulsifying and wetting reagents is necessary, and for maximum efficiency the use of organic solvents for preparing highly dispersed suspensoids appears advisable.

FUNGUS PESTS.

XLV. William B. Brierley. *"On Mutation of Species."* British Medical Journal, 1922, Oct. 21st.

The main genetic bases of "higher organisms" are discussed in relation to the concept of mutation and then in relation to hereditary changes in the protozoa, fungi and bacteria. The concepts of mutation held by microbiologists are considered, and it is shown that they cannot be equated with those applied to "higher organisms." Micro-organisms have not yet been found susceptible to factorial analysis and cytological information regarding the genetic structure and behaviour of their hereditary mechanisms is not available. In the protozoa and fungi, and probably in the bacteria, there is the possibility of the origin of apparently new forms in the normal developmental processes, and it is suggested that "mutations" are due to the selective isolation of such forms.

XLVI. William B. Brierley. *"Some Aspects of Vegetable Pathology in Relation to Human Disease."* British Medical Journal, 1922, Nov. 18th.

The need for extreme caution in making comparison of animal and plant diseases is emphasised, and the lines along which animal and plant pathologists may work in common are suggested. These are mainly comparative morphological, physiological and life history studies of the several pathogens in relation to such problems as systematy, infection, immunity and susceptibility, mutation and other genetic aspects, epidemiology, technique, etc. A plea is made for the definite recognition of a science of medical mycology with adequate teaching and research opportunities.

XLVII. William B. Brierley. *"Comparative Pathology of Plants and Animals."* British Medical Journal, 1922.

The idea of disease accepted in general pathology is that of the invasion of a defensive host by an active parasite, a see-saw balance in which there is an inverse relationship between the health and vigour of the host and the incidence and virulence of the disease. This concept is criticised and evidence given that in diseases of plants it is not necessarily true. The data at present do not allow of such a generalisation and each particular disease complex must be considered separately. The disease complex is

regarded as the co-ordinated resultant of the activities of the host and parasite each, within the limits of its hereditary constitution, being modifiable by the environment. Lines of comparative research in animal and plant pathology are suggested.

XLVIII. J. Henderson Smith. *"The Killing of Botrytis by Heat, with a Note on the Determination of Temperature Co-efficients."* Annals of Applied Biology, 1923. Vol. X.

When a mass of spores of *Botrytis cinerea* is exposed to the action of moist heat by immersion in water, the individual spores are not all killed simultaneously. A few die quickly, a few after prolonged exposure, and the majority at intermediate periods. The whole process, when the numbers dead at successive intervals of time are plotted against the time, gives a smooth curve, of sigmoid and approximately symmetrical shape. The higher the temperature used, the more quickly does the reaction proceed; but at all the temperatures examined, ranging from 37° C. (where 8-10 hours are necessary for its completion) to 50° C. (where the last spore is killed in about 180 seconds) the curve has the same shape, and the process is exactly the same, except for the change in speed. In this respect the action of heat differs from that of phenol, where the shape of the curve changes progressively as the strength of phenol is raised, from the sigmoid type into a J-type and eventually into a strictly logarithmic curve. The difference is assigned to the occurrence with phenol of a stage of penetration, during which the poison is making its way through the external coat of the spore, a stage which is absent in the case of heat.

The shape of the curve agrees excellently with a recognised type of frequency distribution, and can be adequately and reasonably explained by supposing that the individual spores differ in their susceptibility to the action of heat.

The effect of temperature on the velocity of the reaction is unusually great, and is well expressed by the formula of Arrhenius, if the temperature is reckoned from 0° C. instead of from the absolute temperature. By combination of the formula for the curve and the formula for the temperature-velocity relationship, it is possible to express completely for the spores of Botrytis the whole of the killing process within the limits and under the conditions used in these experiments.

XLIX. J. Henderson Smith. *"On the Apical Growth of Fungal Hyphæ."* Annals of Botany, 1923. Vol. XXXVII. pp. 341-343.

The fungal hypha grows in length exclusively at the tip, and the portion of the hypha behind the extreme tip never elongates after it is once formed. This was determined by direct measurements in a series of fungi selected from widely separated and representative genera, and may be taken as a general rule applicable to all, or at least to most, fungi. In algæ, growth may be apical or may be intercalary; in filamentous bacteria it is intercalary, each segment elongating for itself and at the same rate as the others.

L. Sibyl T. Jewson and F. Tattersfield. *"The Infestation of Fungus Cultures by Mites."* Annals of Applied Biology, 1922. Vol. IX. pp. 213-240.

Mites are a serious pest of fungus cultures. The species that most frequently occur are *Aleurobius farinæ* and *Tyroglyphus longior,* with an occasional infestation with *Glyciphagus cadaverum.*

They can be controlled by exposing the cultures to the vapour of Pyridine, after which treatment the fungi can be sub-cultured safely. An exact description of the application of the method is given. (Commercial Pyridine is as effective as the pure material.)

If these pests occur in laboratory apparatus, they can be eliminated by the application of strong ammonia. Ammonia and its vapour are very rapidly effective against mites, but they should not be allowed to come into contact with cultures of fungi for too long a period of time in too high a concentration.

Pyridine is shown to have a slight toxic action to fungi, and to inhibit growth completely in certain concentrations which, however, are not at all likely to be objectionable in practice, especially if the treated cultures are sub-cultured.

A brief analysis of the toxic action of Pyridine on both mites and fungi is given.

(*a*) In the case of mites, minute doses have so powerful a paralysing action as to render it probable that Pyridine is specific in its toxic effect to these pests.

(*b*) In the case of fungi, the action of Pyridine upon the germination and growth of *Aspergillus niger* was closely studied. It is shown that up to about .25%, Pyridine has apparently very little toxic action and no feeding effect, but that above this concentration the toxicity increases with great rapidity. It is shown, however, that the toxic action is one of inhibition of germination and that the neutralisation of the base up to 0.6%, the highest concentration tested (even though spores have been exposed to its action for three weeks), permits growth to take place rapidly. Pyridine acts chiefly as a poison through its basic properties but not by the change in the pH of the medium which ensues on its addition.

WART DISEASE OF POTATOES.

LI. William B. Brierley. *"Some Research Aspects of the Wart Disease Problem."* Report of International Potato Conference, London, 1921.

The empiricism of present control methods is emphasised. The disease is a complex state depending upon the physiology and genetical constitutions of the host and the fungus, and this dual entity exists in relation to a changing environment. The several factors in this complex and their relation to the immunity or susceptibility of potato plants to wart disease, are discussed. The problems under investigation at Rothamsted—tuber quality of immunes and non-immunes, nature of immunity, germination and infection studies, soil sterilisation, etc.—are indicated, and other aspects of wart disease research suggested.

LII. W. A. ROACH. *"Studies in the Varietal Immunity of Potatoes to Wart Disease* (SYNCHYTRIUM ENDOBIOTICUM SCHILB., PERC.)." *Part I.—The Influence of the Foliage on the Tuber as shown by Grafting.* Annals of Applied Biology, 1923. Vol. X. pp. 142-146.

Grafting experiments of a preliminary nature have been carried out to throw light on the functions of the various organs of the potato plant in rendering the tubers immune or susceptible to Wart Disease (*Synchytrium endobioticum* Schilb., Perc.).

Composite plants were built up by grafting in the following ways :—

3 plants of the type	Immune	grafted on	Immune
3 ,,	,,	Susceptible	,,	,,
4 ,,	,,	Immune	,,	Susceptible
2 ,,	,,	Susceptible	,,	,,

The results indicate that the character of the foliage has no influence on the immunity or the susceptibility of tubers to Wart Disease.

It follows that no compound synthetised in the leaves is likely to be responsible for separating potatoes into "immunes" and "susceptibles." The investigation is being continued with the view of finding, if possible, the chemical differences corresponding with the biological differences between immune and susceptible varieties.

TECHNICAL PAPERS.

CROPS AND CROP PRODUCTION.

LIII. E. J. RUSSELL. *"The Barley Crop. A Study in Modern Agricultural Chemistry."* Journal Inst. Brewing, 1922. Vol. XXVIII. pp. 697-717.

Barley, like wheat, flourishes best in relatively dry conditions, and the map showing its distribution in England and Wales is much like an inversion of the rainfall map. In Norfolk it occupies no less than 15% of the land in cultivation and in other counties of low rainfall it occupies between 9% and 14%; in the wetter counties, however, it occupies much less. The yield is chiefly determined by the quantity of nitrogen supplied. When barley is grown year after year on the same ground at Rothamsted the yield steadily falls off for some reason which cannot yet be found. This falling off is less with farmyard manure than with artificial fertilisers. In ordinary farm practice there is no indication of falling yields, but rather the contrary; given adequate manuring, however, the yield is still limited by the season and the strength of the straw.

It is often stated that the quality or malting value of the barley is inversely related to the nitrogen content of the grain, and where large differences are concerned this is generally true. But on any given farm it does not appear that the nitrogen content is much affected by the manuring so long as the conditions are not profoundly altered; the valuation also is not influenced in any regular way.

High malting value seems to be associated with favourable conditions during the second part of the plant life when vigorous growth is followed by good ripening. These conditions almost necessitate a low nitrogen content since nitrogen assimilation occurs mainly in the early part of the plant life ; if there is vigorous growth afterwards it is mainly an accumulation of non-nitrogenous material. In these conditions, therefore, low nitrogen content would be related to malting value. But a low nitrogen percentage might equally result from a low nitrogen intake in the early life of the plant, and in this case there would be no necessary relationship with malting value.

LIV. E. J. Russell. *"Report on the Experiments on the Influence of Soil, Season and Manuring on the Quality and Growth of Barley, 1922."* Journal Inst. Brewing, 1923. Vol. XXIX. pp. 624-654.

Experiments have been made on a uniform plan on a number of farms known to grow barley well. The yields are given on p. 104, as also are the percentages of nitrogen and the values assigned by the maltsters. As this is the first year of the experiments, no conclusions are drawn ; the following results, however, were obtained :—

Nitrogenous manure (sulphate of ammonia) produced its usual effect of increasing the yield by about 5 bush. for 1 cwt. sulphate of ammonia, excepting only in two or three readily explained cases. The valuation was usually unaltered, but in one case it was increased and in two cases reduced.

Phosphates were ineffective at several centres on heavy soils where they would normally be expected to act. On the very light sand they apparently depressed the crop. We believe this to be a true effect attributable to the well-known action of phosphates in accelerating maturation. If this is confirmed by later observations it will necessitate a modification in the manurial treatment of barley on light land.

Contrary to our expectation in this bad season, potassic fertiliser was without effect on the valuation, although it had in several cases a marked effect in increasing yield.

The indication of this season's experiments are that a farmer can vary his manurial treatment within the limits of usual practice without influencing the maltsters' valuation.

The nitrogen content was usually related to maltsters' valuations when the barleys from different farms were compared, but the relationship was much less marked (only about half) when the barleys from differently manured plots on the same farm were compared. This result agrees with that already recorded above.

FERTILISERS.

ORGANIC MANURES.

LV. E. H. Richards and G. C. Sawyer. *"Further Experiments with Activated Sludge."* Journal of the Society of Chemical Industry, 1922. Vol. XLI. pp. 62T-71T.

If activated sludge is aerated for a short period in an ammoniacal solution there is no loss of nitrogen, any nitrogen not

found as ammonia or nitrate in the effluent being recovered in the sludge. There is considerable evidence that the extra nitrogen in activated sludge, over and above that found in the old type sludges, is derived from the ammonia of sewage. There is no evidence of fixation of atmospheric nitrogen. The numbers of protozoa in well-activated sludge approximate to 1,000,000 per gram of wet sludge. The cell content of these organisms alone may account for a large proportion of the extra nitrogen. There is complete correlation between the numbers of active protozoa and bacteria in activated sludge under varied conditions of working.

Observations made in working the experimental tank at Harpenden Sewage Works confirm the laboratory experiments designed to find the source of the extra nitrogen content of activated sludge compared with ordinary sewage sludges. They afford no evidence of fixation of atmospheric nitrogen, but suggest that in addition to colloidal nitrogen, ammonia is removed from the sewage by physical or biological means, or both. The proportion of total nitrogen in the Harpenden sewage recovered in normal working by the activated sludge process is greater than in the older methods of sewage purification, *viz.*, 15% compared with 10% by precipitation and 4% by septic tanks. With sewage of half the average strength and supplying twice the normal volume of air per gallon of sewage, the recovery of nitrogen was as high as 27% of the total nitrogen in the sewage. Field trials show that activated sludge has a high manurial value in marked contrast with the old type sewage sludges tested on the Rothamsted farm in past years.

LVI. H. J. PAGE. *"Green Manuring."* Journal of Ministry of Agriculture, 1922. Vol. XXIX. pp. 104-112; 240-248.

Green manuring is discussed as a substitute for dung, the supply of which is insufficient. Variation in type of soil, climate, system of cropping and the like, necessitates different systems of green manuring; similarly the maintenance of productive soils in good heart by green manuring is a problem distinct from that of building up the fertility of run-down or naturally infertile land. Thus such systems of green manuring as find application in this country vary considerably from district to district. Although the beneficial effect of green manures, and of dung, depends on a variety of factors (which are discussed in detail), the prime function of either is to supply humic material to the soil. Artificials can fulfil most of the other functions of green manures or dung, but not this one.

LVII. H. J. PAGE. *"Saving Expense by Green Manuring."* Modern Farming, 1923. Vol. VI. No. 9.

In seeking to develop the use of green manuring as a substitute for dung, one of the greatest difficulties encountered is that of fitting the green crop into the rotation, without disturbing the latter. In practice this resolves itself into growing the green crop (i.) during the autumn and winter before roots, (ii.) in early autumn before winter corn. The first method finds application in potato districts (of which instances are quoted), but its feasibility as a preparation for mangolds or swedes is uncertain, and merits

trial. The second method is difficult to apply in many seasons, except at the end of a bare fallow, when mustard is often grown for turning in before winter corn. Various details of green manuring practice are described.

LVIII. E. J. RUSSELL. *"The Possibility of Using Town Refuse as Manure."* Journal of Ministry of Agriculture, 1922. Vol. XXIX. pp. 685-691.

Six types of refuse are sent from four towns :—

1.—"Dry" refuse : the contents of refuse bins and "dry" ashpits.

2.—Separated dust : finely divided material separated mechanically from the dry refuse through a ⅜in. or 5/16in. sieve.

3.—"Mixed" refuse : the contents of privy middens and ash closets.

4.—Night soil : the contents of pails containing crude fæcal matter only; this is produced in towns where the pail system is used. When dried and granulated it contains some 5½% nitrogen, 5½% phosphates and 2½% potash.

5.—Mixed night soil : *i.e.*, dry refuse, plus night soil, or separated dust, plus night soil, mixed in certain proportions. A 50% mixture offered at Rochdale contains 2.9% nitrogen, 3.6% phosphates (half being soluble and half insoluble), and 1.2% potash.

Market and slaughter-house refuse are sometimes mixed with 1, 2, 3 and 5.

6.—Street sweepings and other wastes.

Of these, 4 and 6 are well known to farmers.

The dry refuse in the more progressive towns is sorted over for the removal of bottles, metals and other saleable commodities. It is usually in good physical condition for putting on to the ground and for lightening a heavy soil. Its composition, however, is not particularly good in spite of its smell. Improvement is effected by enriching with a certain amount of other waste matter, such as street sweepings, slaughter-house refuse, stable manure, etc., and the final analysis comes out something like the following :—

Organic matter	25 %-40 %
Nitrogen	0.4%-0.6%
Phosphoric acid (P_2O_5)	0.3%-0.5%
Equivalent to tricalcic phosphate ($Ca_3(PO_4)_2$)	0.7%-1.1%
Potash (K_2O)	0.3%-0.5%

Farmers who use this material speak well of it and agricultural experimenters could well include it in their list of substances to be tried on the field.

ARTIFICIAL FERTILISERS.

LIX. H. J. PAGE. *"The Agricultural Value of Modern Fertilisers."* Raw Materials Review, 1923. pp. 111-112.

A discussion of the relative merits of present-day nitrogenous, potassic, phosphatic and organic fertilisers.

LX. E. J. Russell. *"Recent Changes in Artificial Fertilisers."* The Field, 1922.

LXI. E. J. Russell. *"The Economical Use of Artificial Manures on the Farm."* Address to Bath and West and Southern Counties Society, June, 1921.

LXII. E. J. Russell. *"Phosphatic Fertilisers."* Journal of Ministry of Agriculture, 1923. Vol. XXIX. pp. 234-240.

LXIII. E. J. Russell. *"Manures for Milk: Lime, Slag, and How to Use Them."* The Milk Industry, 1922.

LXIV. E. J. Russell. *"The Dairyman and his Grass Land."* The Milk Industry, 1923.

LXV. E. J. Russell. *"Manurial Dressings Worth Trying."* Modern Farming, 1922.

LXVI. E. J. Russell. *"Top-dressing as a Modern Farming Operation."* Modern Farming. pp. 1-22.

A series of papers written for farmers giving the results of recent experiments with fertilisers and showing how they may be applied on the farm.

LXVII. E. J. Russell. *"Soil Sterilisation: Why and How to do it."* The Fruit Grower, 1923.

LXVIII. E. J. Russell. *"Agricultural Chemistry and Vegetable Physiology."* Annual Reports of the Chemical Society, 1921. Vol. XVIII. pp. 192-209. (1921: E. J. Russell. 1922: H. J. Page.)

LXIX. E. J. Russell. *"Annual Report on Soils and Fertilisers."* Soc. Chem. Ind. Annual Reports on Applied Chemistry. (1921: E. J. Russell. 1922: H. J. Page.)

LXX. E. J. Russell. *"Science and Modern Farming."* Journal Newcastle Farmers' Club, 1921.

LXXI. E. J. Russell. *"Modern Application of Chemistry to Crop Production."* Inst. Chem. Lecture Publication, 1921.

LXXII. E. J. Russell. *"Science and Crop Production."* Scottish Journal of Agriculture, 1922. Vol. V.

LXXIII. E. J. Russell. *"The Work of the Rothamsted Experimental Station."* Journal of Ministry of Agriculture, 1922. Vol. XXVIII. pp. 777-787.

LXXIV. E. J. Russell. *"Rothamsted and Agricultural Science."* Evening Discourse Royal Institution, February, 1923.

LXXV. E. J. Russell. *"The Artificial Feeding of Crops."* Discovery, 1923.

LXXVI. E. J. Russell. *"The Influence of Geographical Factors on the Agricultural Activities of a Population."* Geographical Teacher, 1923.

LXXVII. *"Catalogues of Journals and Periodicals in the Rothamsted library."*

BOOKS PUBLISHED DURING 1921-22.

A. D. Imms. *"A General Textbook of Entomology."* Methuen & Co., Ltd. (in the press).

E. J. Russell. *"Farm Soil and its Improvement."* Benn Bros. (in the press).

Written for the working farmer.

E. J. Russell and Members of the Staff of the Rothamsted Experimental Station. *"The Micro-organisms of the Soil."*

A series of lectures delivered at University College, London. Longmans, Green & Co. (Rothamsted Memoirs on Agricultural Science).

Winifred E. Brenchley. *"Manuring of Grass Land for Hay."* Longmans, Green & Co. (in the press).

This monograph embodies a comparison between the aspects of the Park Grass plots at the present time with that about 40 years ago when Lawes, Gilbert & Masters published their accounts of the experiment.

Complete separation of samples of hay from every plot were made in 1914 and 1919, and the analysed results have been compared with those of the four earlier analyses up to 1877. In every case an outline is given of the present condition of the plot, with lists of the species occurring and their relative abundance. The principal changes during the experimental period are outlined, particular attention being given to the effects brought about by regular liming of one half of some of the plots since 1903.

The most striking alteration brought about by liming in the botanical composition of the herbage is the remarkable increase in the amount of foxtail (*Alopecurus pratensis*) on the heavily manured plots, and the corresponding, though less marked, reduction in Yorkshire Fog (*Holcus lanatus*) and vernal grass (*Anthoxanthum odoratum*).

The figures of the botanical analyses are given in the form of tables in which different types of manuring are grouped together, and certain of the results are more clearly indicated by graphs. The results as presented deal solely with the Rothamsted plots on heavy soil and no attempt is made to compare them with other more or less similar work on different types of soil elsewhere.

The intention of the monograph is to attempt to round off and complete the work begun by Lawes & Gilbert in order to suggest possible lines along which future developments of experimental work on meadow land might profitably extend.

THE CROP RESULTS.

OCTOBER, 1920, TO SEPTEMBER, 1921.

This was perhaps the most remarkable season we have had, almost every month giving some new record.

October, 1920, was a beautiful month; fine, sunny and dry, with gentle N.E. winds. The clock was changed on the night of Sunday, October 17th, thus facilitating morning work. Winter ploughing was pushed well forward and potato work was done in dry and comfortable conditions.

November also was dry (indeed some places were short of water), so that all corn sowing and root carting were readily completed.

After the middle of December there was much rain, but the weather continued mild; the arable land lay wet, but as against this the grain grew well and the bullocks remained out throughout January.

January of 1921 was the warmest January on record; on no less than 23 days in the month the maximum temperature rose to 48° or above. There was no frost that survived the morning sun, and indeed by the end of the month there had been only four or five really cold days since Christmas. On January 25th, at about 10 p.m. an arc of a lunar rainbow was seen in the north by Messrs. Bowden and Seabrook.

February was dry throughout, there being only 0.21 inches of rainfall against the average 2.02 inches. There had been no such dry February since 1895; it was, however, colder than January. The winter was one of the mildest within our recollection, much facilitating work in the gardens.

In March the weather turned cold, but the drought continued; there fell just over one inch of rain. The dry weather favoured the suppression of the black-bent grass in Broadbalk wheat, but it caused some injury to the spring sown corn. April began dry, but nearly half-an-inch of rain fell on the 13th, and the total fall for the month was only 0.55 ins. less than the average.

May, like April, had somewhat less than the average rainfall (.45 ins. less), but was beautifully warm.

June was the driest June for 100 years. The farm well ran dry about May 25th for the first time since it was made in 1913, and water had to be carted to the farm. The weather set in dry and hot, and continued like this all through the summer and autumn, making 1921 a year to be remembered as one of the best by all holiday makers.

The drought and hot weather continued right through August and September; the harvest was probably the earliest and the finest for weather we have had. Broadbalk was cut on July 27th, the earliest date since 1896. Many farmers cut and carted their corn on the same day.

The rapidity with which the harvest was cleared away allowed unusually good facilities for stubble cleaning. Good work was done with a Ransome tractor broadshare, which cut all tap roots of weeds, broke up the surface soil to a depth of 3 inches and left it ridged up. While the dry weather lasted the grass and other weeds were dying, and when rain came the weed seeds germinated

and could be killed by cultivation. The hot dry autumn was expected to have a very beneficial effect on the soil, and we looked forward with great confidence to good fertility conditions in 1922.

The effects of this remarkable season on the crops were as follows :—

1.—Wheat promised to be the crop of the year. It looked well throughout the summer and responded to nitrogenous dressings. On our farm the yields did not come up to expectation, but generally the yield was excellent, the average for England and Wales being 35.3 bushels as against the 10 years' average of 30.7 bushels.

2.—Oats yielded satisfactorily.

3.—Barley came very short in the straw, but the yields were better than seemed likely. An increase of 9 bushels resulted from a top-dressing of 1 cwt. of sulphate of ammonia.

4.—Swedes failed entirely.

5.—Potatoes almost failed, giving only 2 or 3 tons per acre; there was much second growth.

6.—Mangolds were hampered by the summer drought, but grew well after harvest and finally yielded well.

7.—Clover sown in 1920 did well, the first cut especially being good. Throughout the country the seeds hay had usually yielded pretty well. The seeds sown in 1921, however, failed, so that we were constrained to keep some of the 1920 ley down till 1922—a practice which does not usually answer and was not successful on this occasion.

8.—The permanent grass, on the other hand, gave poor results.

Of the fertilisers nitrogen gave its usual increase as shown on p. 85.

Phosphates (superphosphate, basic slag, but not bone meal on our farm) produced a very visible effect by the middle of June in hastening the ripening processes in barley, the phosphate treated plants being well headed out, while those without phosphate were not; finally phosphates caused a distinct increase in crop (Little Hoos field).

Basic slag produced no visible effect on the grass land.

Potassic fertilisers had no visible effect on barley up to June.

It was remarkable during this season that the barley on the acid plot on Agdell field (No. 2 complete artificials and clover) showed no signs of the failure which had marked the wheat and swede crops.

OCTOBER, 1921, TO SEPTEMBER, 1922.

The drought continued throughout October; in many districts the water supply gave serious trouble. It was not till November that the rainfall began and then it was less than the average.

With the new year, however, conditions became different. January and February were both wet, and April was specially so. In addition the weather was bitterly cold, making everything very backward and causing damage to the winter corn.

In the gardens the bulbs had made a magnificent show and the fruit trees were full of blossom; this was probably associated with the complete ripening of the wood in the autumn of 1921.

May was hot and dry, culminating in a very hot week near the end, and it looked as if we might have another 1921 summer, but June, though dry, was colder and less sunny, and the weather progressively deteriorated as the season advanced. The summer was a byword among farmers and holiday-makers. July was not only cold and sunless, but very wet as well, there being almost double the average rainfall (4.6 ins. instead of 2.4 ins.). August and September remained cold and sunless, and differed only in that August was not wetter than usual, while September had 50% more than the average rainfall. The harvest was much delayed; it had been one of the earliest on record in 1921; it was one of the latest and most protracted in 1922. Old farmers compared it with that of 1879; indeed some said it was worse. The comparison was ominous, for it foreshadowed suffering not only from the weather but from the severe financial crisis which set in, worse than any in the last 30 years. October was much drier and had more sunshine, but the winds were mostly cold; arrears of cultivations were, however, partly overcome.

The yields of crops were far better than might have been expected in view of the wretched weather conditions. Spring growth was poor, but later growth was very marked; indeed the results were so remarkable that we cannot help connecting them with the thorough baking given to the soil by the hot dry autumn of 1921. Taking the crops in detail, grass, while giving a poor yield of hay in June, made better growth afterwards, and the grazing results over the season were considerably more satisfactory than in 1921; thus on the permanent grass plots of Great Field the results were :—

	1921	*1922*
Yield of hay, cwt. per acre (end of June)	26.4	20
Live weight increase in sheep, lb. per acre (end of September) . . .	60 / 90	116

Barley made a splendid start as the March weather allowed an excellent seed-bed to be formed, but the young plants were seriously checked by the drought in May and June; some of them began to turn yellow as if the ripening processes were already beginning. The July rain caused a resumption of growth, but the absence of sun and the continued rain seriously interfered with ripening. In the end the yield of grain was normal,* but the quality was execrable; indeed, experienced barley buyers described the season as one of the worst for many years. Some of the results were :—

	Hoos Field 4a	Long Hoos	
	Barley	*Malting Barley*	
	Complete Manure	No Manure	Complete Manure
Yield . . .	31	25.8	32.6
Average for last 10 years . .	32	—	—
Value per quarter	—	36/-	31/-

* The average yields of cereals for England and Wales were lower than in 1921, and, in the case of the oats below the ten years' average.

Unfortunately much of our barley heated in the stack, so that the projected experimental scheme could not be carried out.

Wheat suffered much from the cold spring, the May and June drought, the lack of sunshine in July and the wet harvest; it yielded miserably on our farm though the general average throughout the country was not low.

When we turn from these early sown grain crops to the late sown, late growing, big leaved crops which are not required to produce seed, the picture is much brighter.

Swedes and potatoes both gave record crops; mangolds also gave good yields; on the completely manured plots the yields in tons per acre were :—

	1922	1921	1920	1919	1918
Potatoes .	9	3½	4	5½	5
Swedes . .	30.4	Nil	17	9	Nil
Mangolds .	30.35	27.75	28.75	18.17	28.30

We can summarise the effects of the season by saying that vegetative growth was poor during the first part, but remarkably good during the second part, and we are disposed to connect this good growth with the hot dry fallowing of the previous autumn. Seed production, on the other hand, was very adversely affected, indeed few seasons of recent years have brought out so clearly the contrast between the two processes.

The effect of manures was interesting. Nitrogenous fertilisers acted on all crops. The increase produced by 1 cwt. sulphate of ammonia in the field experiments was remarkably close to that normally expected :—

INCREASES PRODUCED BY 1 CWT. SULPHATE OF AMMONIA IN THE FIELD EXPERIMENTS OF 1922.

	Usually expected	*Obtained in 1922*
Barley	6½ bush.	6¼ bush.*
Wheat	4½ ,,	3.7—5.0 bush.†
Potatoes	20 cwt.	20 cwt.
Swedes	20 ,,	20 ,,

* Taking the mean of all centres the value is 5½ bushels.
† For early and late dressings respectively.

Phosphates were curiously ineffective in 1922, even on the swede and barley crops where one would have expected them to act well. During the early part of the season the usual effects of stimulation of early growth were produced. Barley and swedes receiving phosphates both started earlier into growth, and the swedes were sooner ready for hoeing than where phosphate was withheld.

Potassic fertilisers, on the other hand, proved very effective. Even barley responded (which does not usually happen at Rothamsted), and the response was as marked as that of nitrogen (which is even more unusual). The effect on potatoes was very

marked, especially where no dung was applied, and formed one of the most striking demonstrations of the year. Some of the figures were :—

	Barley bush.	*Potatoes* (KERR'S PINK) tons per acre *No Dung*	*Dung*
Complete manure	32.6	8.3	9.5
No potash . .	27.0	2.5	8.0

The Barnfield mangolds were in May badly attacked by a small beetle, *Atomaria linearis*, which seriously affected all plots except those receiving rape cake.

EXPENDITURE AND CASH RETURNS PER ACRE.

The classical fields of the farm are used continuously for their appropriate experiments, but the remaining fields are not. After an experiment is completed the land goes back to ordinary cultivation so as to restore uniformity of conditions as far as possible. Usually about 170 acres are thus farmed. The accounts for this farmed land are kept quite separate from those for the experimental areas, and they show approximately what an ordinary farmer might spend and receive.

The figures are worked out by precisely the same method as in the last report. They include only money paid out or brought in; there are no allowances for interest or farmers' remuneration beyond £175 per annum, which is spread over 178½ acres; also no allowance is made for residual manurial values. Depreciation of horses and dead stock is, however, included.

	EXPENDITURE PER ACRE.		CASH RETURNS PER ACRE.		
	Oct. 1920–Sept. 1921	Oct. 1921–Sept. 1922	Oct. 1919–Sept. 1921*	Oct. 1920–Sept. 1921	Oct. 1921–Sept. 1922
	£ s.	£ s.	£ s.	£ s.	£ s.
Wheat	13 5	11 4	20 6	13 3	6 12
Oats	16 12	10 10	18 12	14 4	11 11
Barley	19 19	12 16	18 1	15 3	6 1
Roots	38 17	31 5		21 8	17 13
Potatoes . . .	47 11	—	26 12	17 16	—
Clover	12 1	5 9†		8 16	3 6
Grass:					
Temporary hay	6 7		8 13	4 13	
Permanent hay			4 6		

	CASH BALANCE (+) OR DEFICIT (—) PER ACRE.		
	Oct. 1919–Sept. 1920	Oct. 1920–Sept. 1921	Oct. 1921–Sept. 1922
	£ s.	£ s.	£ s.
Wheat	+ 5 5	— . 2	— 4 12
Oats	+ 4 0	— 2 8	+ 1 1
Barley	+ . 5	— 4 16	— 6 15
Roots		—17 9	— 13 12
Potatoes	—31 4	—29 15	—
Clover		— 3 5	— 2 3
Grass: Permanent hay . . .	+ . 16	— 1 14	—
Temporary hay . . .	— 1 11		—
Total farming loss . . .	Profit £410 (176 acres)	£960 - 16 (173 acres)	£308 - 11 (140 acres)

* As stated in the 1918-20 Report, the figures there given include the estimated value of unsold material. The sales are now complete and the final figures are given here.
† Carried on from 1921: see p. 56.

From 1920 onwards the financial results are deplorable, and they show clearly why many of the arable farmers to-day are in their present position.

DETAILS OF PLOUGHING COSTS.

Cost of Ploughing One Acre of Land.

Horses.	1921	1922	Tractor.	1921	1922
21 hours	@ $9\frac{3}{4}$d. = 17/-	@ 7d. = 12/3	3 hours	@ 4/- = 12/-	@ 3/6 = 10/6
Ploughman : $1\frac{1}{2}$ days	@ 8/5 = 12/7	@ 4/$10\frac{1}{2}$d = 7/3	Driver . 3 ,,	@ 1/$2\frac{1}{2}$ = 3/7	@ 10d. = 2/6
Implements	2/-	1/6	Implements	2/6	2/-
	31/7	21/-		18/1	15/-

Approximate Paraffin and Oil Consumption for Ploughing 3 Furrows.

	Austin	*Titan*
Paraffin per acre .	2 to 3 gals. : average $2\frac{1}{2}$	$3\frac{1}{2}$-$4\frac{3}{4}$ gals. : average $4\frac{1}{4}$
per hour : approx.	1 gal.	$1\frac{1}{2}$ gals.
Oil per acre . .	0.06 gals.	.66 gals.
Time to plough one acre about . .	$2\frac{1}{2}$ hrs.	3 hrs.

The farm manager supplies the following notes on the tractors during the season 1921-22.

	Hours of Work.	Paraffin consumed at above rates.	Oil Consumed.*	Petrol Consumed.
Austin . . .	$835\frac{1}{2}$	$835\frac{1}{2}$ gals.	17 gals.	54 gals.
Titan . . .	$247\frac{1}{2}$	$371\frac{1}{2}$,,	31 ,,	
Totals .	$135\frac{1}{2}$ days	1207 gals.	48 gals.	54 gals.

* Calculated at average rates for Austin 1 gal. per wk., Titan 1 gal. per day.

The consumption of paraffin per hour seems to be the most constant factor for purposes of calculating. The difference in the cost of various operations is brought about mainly by the width of the implement used and the speed maintained.

The number of hours exclusive of threshing = 870 or about 109 working days, equivalent to 6,090 horse hours, $2\frac{3}{4}$ horses per annum.

While a horse may put in 280 days' work, a good deal of this is of a maintenance type and not strictly seasonal. The tractor hours probably represent the time put into the important work of the farm by $3\frac{1}{2}$ horses.

Types of work done :—

- Ploughing
- Sub-soiling.
- Cultivating.
- Drag + harrow.
- Roller + harrow.
- Roller only.
- Cutting and binding.
- Threshing.

Overhauling at end of season :—

Parts . . £3 11 8 (supplied free).
Labour . £11 0 0

WOBURN EXPERIMENTAL FARM.

REPORT FOR 1922 BY DR. J. A. VOELCKER.

SEASON.

Beginning with a warm, dry October 1921, autumn cultivation and sowing made good progress. The winter was marked by little rain and only occasional frosts; it was followed by a cold and sunless spring which retarded the growth of winter-sown crops, and by a very wet April which delayed the sowing of spring crops. The early part of May was cold and wet, the latter hot and dry, this continuing throughout June and making the obtaining of a good swede crop difficult. In July rainfall was excessive, and, from then to harvest, cold and wet weather, with absence of sunshine, prevented the proper ripening of corn crops, all being considerably damaged by rain. Mangolds, being put in early, were an excellent crop, as also Potatoes, but Swedes were almost an entire failure, and Hay, though a fairly large crop, was not of good quality.

The rainfall for the season was 25.41 inches, there being 193 days on which rain fell. The rainfall was heaviest in July (4.02 ins.), and in April (3.89 ins.); in August and September, 2.07 ins. and 2.48 ins. of rain fell.

FIELD EXPERIMENTS, 1922.

1. *Continuous Growing of Wheat* (Stackyard Field), *46th Season.*

"Red Standard" wheat (10 pecks to the acre) was drilled on October 10th, 1921. Farmyard manure (plot 11B) was ploughed in on October 5th, Rape Dust (plot 10B) on October 8th, and mineral manures given to the several plots at the time of drilling the wheat. The nitrogenous top-dressings were put on May 17th and June 17th, 1922.

The wheat crop was cut on August 11th, stacked August 29th, and threshed on December 22nd.

The results are given on page 62.

The crop results were very similar to those of 1920.

The main features shown are: — The unmanured produce averaged 8.5 bushels of corn with 7 cwt. of straw per acre; farmyard manure gave only 2 bushels more per acre, Rape Dust doing

Continuous Growing of Wheat, 1922 (46th Season).

(Wheat grown year after year on the same land, the manures being applied every year.)

Stackyard Field—Produce per acre.

Plot.	Manures per acre.	Head Corn No. of bushels.	Head Corn Weight per bushel.	Tail corn Weight	Straw, chaff, &c.
			lb.	lb.	cwt. q. lb.
1	Unmanured	8.9	59.7	8	8 0 16
2a	Sulphate of ammonia (=25 lb. ammonia)	1.4	60	—	1 2 24
2aa	As 2a, with 5 cwt. lime, Jan., 1905, repeated 1909, 1910 and 1911 .	8.8	60	12	8 2 0
2b	As 2a, with 2 tons lime, Dec., 1897 .	10	60·	2	9 1 26
2bb	As 2b, with 2 tons lime (repeated), Jan , 1905	9.4	60	6	8 0 8
3a	Nitrate of soda (=50 lb. ammonia) .	13.8	58.2	18	12 2 0
3b	Nitrate of soda (=25 lb. ammonia) .	13.4	59.7	10	11 1 12
4	Mineral manures (superphosphate, 3 cwt.; sulphate of potash, ½ cwt.) .	7 7	60	6	9 0 16
5a	Mineral manures and sulphate of ammonia (=25 lb. ammonia) . .	14 1	61	12	14 1 24
5b	As 5a, with 1 ton lime, Jan., 1905 .	16.7	61	8	16 3 16
6	Mineral manures and nitrate of soda (=25 lb. ammonia) . . .	14.0	60.2	8	13 2 2
7	Unmanured	8.1	60 7	4	6 2 0
8a	Mineral manures and (in alternate years) sulphate of ammonia (=50 lb. ammonia)	4.8	60	36	7 2 24
8aa	As 8a, with 10 cwt. lime, Jan , 1905, repeated Jan., 1918 . . .	9.9	60	12	10 1 12
8b	Mineral manures, sulphate of ammonia (=50 lb. ammonia) omitted (in alternate years) . . .	3.8	60	—	4 2 16
8bb	As 8b, with 10 cwt. lime, Jan., 1905, repeated Jan., 1918 . . .	9.9	60	16	11 0 0
9a	Mineral manures and (in alternate years) nitrate of soda (=50 lb. ammonia)	11.3	59.2	4	11 2 14
9b	Mineral manures, nitrate of soda (=50 lb. ammonia) omitted (in alternate years)	8.0	61.2	6	9 1 0
10a	Superphosphate 3 cwt., nitrate of soda (=25 lb. ammonia) . . .	18.3	60	12	16 0 0
10b	Rape dust (=25 lb. ammonia) . .	13.5	61	8	13 0 24
11a	Sulphate of potash 1 cwt., nitrate of soda (=25 lb. ammonia) . ,	11.8	60	8	14 3 16
11b	Farmyard manure (=100 lb. ammonia)	10.8	59.7	8	13 2 20

better (5 bushels increase); the highest crop was 18.3 bushels of corn per acre from superphosphate and nitrate of soda, the next best, 16.7 bushels, being from minerals and sulphate of ammonia, with lime.

Apparently the 10 cwt. per acre of lime applied last in 1918 to plots 8aa, 8bb, was nearly worked out, but the 1 ton per acre (plot 5b) continued to show an influence, as did, to a slight extent still, the 2 tons (plot 2b) given as far back as 1897.

2. *Continuous Growing of Barley* (Stackyard Field), *46th Season.*

Owing to the wet state of the land it was not possible to drill the barley until April 18th, 1922, when "Plumage Archer" (10 pecks per acre), was sown, the mineral manures going on at the same time. Farmyard manure had been previously (March 13th) ploughed in on plot 11B, and Rape Dust (plot 10B) applied on April 12th.

The nitrogenous top-dressings were given on June 17th and July 3rd.

The barley, despite an unfavourable season, grew better than usual; this may in no small measure be due to selected seed being used; indeed, the variety ("Plumage Archer") proved, over the farm generally, to answer considerably better than the other varieties, "Bevan's Archer" and "Chevalier," also grown. The newly-limed plots (3aa and 3bb, limed January, 1921,) seemed, from the outset, to be better than the unlimed. The crop was cut on September 11th, stacked October 11th, and threshed on December 21st.

The results are given on page 64.

The crop was the highest recorded since 1917, the unmanured produce being 13.5 bushels of corn and 9½ cwt. of straw per acre. The highest yield was 38.3 bushels of corn per acre, with farmyard manure; the next highest, 33.8 bushels, with minerals and nitrate of soda. Unlike with wheat, rape dust gave but a poor crop. As in previous years, the use of potash (plot 11a) seemed to benefit the barley more than that of phosphate. The most striking results, however, are those showing the influence of lime. Not only have there been notable increases in plots 2B, 2BB, 5AA, 5B, 8AA, and 8BB, as compared with the corresponding unlimed plots, but, where lime was put on plots previously treated for many years with nitrate of soda, there was a marked restoration of the yield, though the lime had only gone on the year previous. It would appear from this that not only where sulphate of ammonia is used continually is lime a necessity, but that lime will also tell where nitrate of soda has been similarly used.

It should be mentioned that some of the barley area was attacked by "gout-fly," and this was investigated on the spot by Mr. Frew, of the Entomological Department. The plots least affected were the ones most highly manured.

Continuous Growing of Barley, 1922 (46th Season).

(Barley grown year after year on the same land, the manures being applied every year.)

Stackyard Field—Produce per acre.

Plot	Manures per acre	Head Corn: No. of bushels	Head Corn: Weight per bushel	Tail corn: Weight	Straw, chaff, &c.
			lb.	lb.	cwt. qr. lb.
1	Unmanured	14 9	49.5	19	10 2 18
2a	Sulphate of ammonia (= 25 lb. ammonia)	4.9	54	—	2 3 12
2aa	As 2a, with 5 cwt lime, Mar., 1905, repeated 1909. 1910, and 1912	6.3	56	—	5 1 8
2b	As 2a, with 2 tons lime, Dec., 1897, repeated 1912	23.6	48.2	40	13 0 24
2bb	As 2a, with 2 tons lime, Dec., 1897, repeated Mar., 1905	24.0	48.2	40	10 3 24
3a	Nitrate of soda (=50 lb. ammonia)	11.4	51	28	6 3 12
3aa	As 3a, with 2 tons lime, Jan., 1921	23.0	47.2	32	16 0 4
3b	Nitrate of soda (=25 lb. ammonia)	17.3	48.2	32	8 3 8
3bb	As 3b, with 2 tons lime, Jan., 1921	21 4	47.5	44	10 0 16
4a	Mineral manures[1]	18.0	49.7	24	10 3 26
4b	As 4a, with 1 ton lime, 1915	19.3	49.7	30	11 1 16
5a	Mineral manures and sulphate of ammonia (=25 lb. ammonia)	13.6	50	24	9 1 8
5aa	As 5a, with 1 ton lime, Mar. 1905, repeated 1916	28.8	49.7	44	14 1 4
5b	As 5a, with 2 tons lime, Dec. 1897, repeated 1912	26 9	48.4	42	15 3 0
6	Mineral manures and nitrate of soda (=25 lb. ammonia)	30 0	48.5	46	16 0 9
7	Unmanured	12.6	48.7	20	8 2 12
8a	Mineral manures and (in alternate years) sulphate of ammonia (=50 lb. ammonia)	2.0	50	—	0 3 12
8aa	As 8a, with 2 tons lime, Dec., 1897, repeated 1912	26 2	48.7	56	16 3 16
8b	Mineral manures, sulphate of ammonia (=50 lb. ammonia) omitted (in alternate years)	1.3	50	—	1 0 0
8bb	As 8b, with 2 tons lime, Dec., 1897, repeated 1912	17.7	50.5	24	12 3 0
9a	Mineral manures and (in alternate years) nitrate of soda (=50 lb. ammonia)	33.8	47.3	76	19 2 6
9b	Mineral manures, nitrate of soda (=50 lb. ammonia) omitted (in alternate years)	27.3	48.5	34	14 1 18
10a	Superphosphate 3 cwt., nitrate of soda (=25 lb. ammonia)	25.1	47	46	14 1 26
10b	Rape dust (=25 lb. ammonia)	10.8	49	26	7 2 4
11a	Sulphate of potash 1 cwt., nitrate of soda (=25 lb. ammonia)	29.1	49	44	17 3 24
11b	Farmyard manure (=100 lb. ammonia)	38.3	49.6	78	19 2 20

[1] Superphosphate 3 cwt., sulphate of potash ½ cwt.

3. *Rotation Experiments.*

The Unexhausted Manurial Value of Cake and Corn

(Stackyard Field).

(*a*) Series C, 1922. Swedes.

The previous rotation being concluded with wheat (1921) following red clover, swedes were put in as the first crop of the new rotation. The drought towards the end of May and throughout June made the swede crop very uncertain; the seed was drilled on June 18th, mineral manures (superphosphate 3 cwt., sulphate of potash 1 cwt., per acre) being applied shortly before (May 26th). A plant was, with difficulty, obtained, and a small crop, though uniform over the area, was grown. A top-dressing of 1 cwt. per acre nitrate of soda was given after singling. The crop was, later on, fed off with sheep, one half with cake, the other half with corn.

(*b*) Series D, 1922. Barley after Swedes.

The swede crop of 1921 being too small to feed off on the land, it was removed, and barley ("Beaven's Archer") drilled on April 11th, superphosphate 2 cwt. per acre and sulphate of potash 1 cwt. per acre having been applied April 7th. 1 cwt. sulphate of ammonia per acre was given later as a top-dressing. Red clover was sown in the barley on May 22nd. The barley was only a moderate crop and was cut on September 30th. It took a long time to cart, owing to bad weather, but was ultimately stacked October 11th, and was threshed December 16th.

The results follow.

Rotation Experiment—the Unexhausted Manurial Value of Cake and Corn. Series D (Stackyard Field), *1922—Barley after Swedes (carted off).*

Plot		Head corn		Tail corn	Straw, chaff, etc.
		Bushels.	Weight per Bushel.	Weight.	
			lb.	lb.	cwt. qr. lb.
1	Corn-fed Plot	22.3	47.5	42	10 1 24
2	Cake-fed Plot	20.3	49	52	9 3 3

The yield was poor, and not equal to the manured plots of the continuous barley series in the same field, where, however, "Plumage Archer" had been grown as against "Beaven's Archer" here. Moreover, the yield after feeding of corn was somewhat above that after feeding of cake.

4. *Green Manuring Experiments, 1922.*

(*a*) Stackyard Field. Series A.

After the growing of green crops (tares and mustard) in 1921 it was decided to make a change in these plots, the whole area of 4 acres being divided into an upper and a lower half, and a rearrangement made by which, while the alternation of green crop and corn crop was kept up, there should be every year one half in

green crop and the other half in corn. Further, it was decided to limit future enquiry to the two green crops, tares and mustard, both in this field and in Lansome Field, and to omit the third crop, rape.

Accordingly, after the green crops of 1921 had been fed off by sheep, wheat was sown over the lower 2 acres, and green crops again on the upper 2 acres. Wheat ("Red Standard") was drilled on October 12th, and winter tares on 1 acre on October 12th. Mustard followed on the remaining 1 acre on May 27th, 1922.

It was very noticeable that the tares were markedly better on that part of the land where in earlier years (since 1911) rape had been grown, than where tares followed tares; a like difference was seen on the lower half with the wheat crop, this being better on the strip that had carried rape than where tares had been the crop. This would seem to open a question as to whether the repetition of the tares crop had not had an injurious effect.

The wheat, following green crops fed on, made little progress, and was a very disappointing crop. It was cut on August 24th, stacked, and threshed December 22nd.

The results follow.

Green Manuring Experiment (STACKYARD FIELD).

Produce of Wheat per acre, 1922—after Green Crops. Series A.

Plot		Head Corn		Tail Corn	Straw, Chaff, etc.
		Bushels.	Weight per Bushel	Weight	
			lb.	lb.	cwt. qr. lb.
1	After Tares fed off	6.9	60	5	7 3 3
2	After Mustard fed off	7.5	58.6	6	8 2 5

These poor results are quite unaccountable, especially when it is remembered that on land only a few yards off in the same field the unmanured yield after 46 years was higher than here. Moreover, not only had very fair green crops been grown in 1921, but these had been fed off by sheep which had 1½ cwts. of cotton cake per acre as well. This opens up a whole series of problems in relation to green manuring, and which call for careful investigation.

The tares on the upper half grew well, were fed off by sheep, in July, 1922, receiving ¾ cwt. cotton cake per acre, and then a second crop of tares was grown, this being similarly fed off along with cake in October. Mustard, sown on May 27th, was fed off with cotton cake, a second crop then grown and this likewise fed off.

(*b*) LANSOME FIELD.

Green crops of tares and mustard had been grown on the old plots of this experiment in the summer of 1921, and were ploughed in towards the end of July. The area was then extended by the addition of 3 more ¼-acre plots, one of tares, one of mustard, and the third left as a control plot. To all the plots alike (now 5 in

number) basic slag at the rate of 5 cwt. per acre, and sulphate of potash 1 cwt. per acre, were given on October 14th, 1921, and tares and mustard again sown. These did not come to much, and so the land was cleaned and green crops again put in on June 28th, 1922, when they grew much better; the mustard was ploughed in August 28th and the tares October 16th, wheat then being drilled over the whole area.

5. *Malting Barley Experiments.*

Experiments were carried out, in conjunction with Rothamsted and other centres, on the influence on yield and quality produced with barley by different manures and combinations of these. The variety of barley supplied was "Plumage Archer."

(*a*) WARREN FIELD.

The field selected at Woburn was the heaviest one on the farm, the soil being a fairly heavy sandy loam, just on the junction of the Lower Greensand and Oxford Clay formations. Previously the land had grown a crop of mangolds which had had 8 tons per acre of farmyard manure. Five plots of ¼-acre each were marked out, and barley—at the rate of 10 pecks per acre—was drilled on April 19th, 1922. Mineral manures were applied at the time of sowing the seed, in accordance with the plan given below, the nitrogenous top-dressings being applied later, *viz.*, on June 20th.

The crops grew well and showed but small differences until nearing harvest, when, owing to the unfavourable weather, they got somewhat "laid," and ripening was much retarded. Plot 2 (complete artificials) was the least "laid," and plots 3 (no nitrogen) and 4 (no potash) were rather before the others in ripening.

The crops were cut September 9th, 1922, and threshed January 24th, 1923.

The results are given in the following table:—

Malting Barley Experiments (WARREN FIELD), *1922.*

Produce of Barley per acre, after Mangolds (manured).

Plot	Manures per acre	Head Corn		Tail Corn	Straw, Chaff, etc.
		Bushels	Weight per Bushel	Weight	
			lb.	lb.	cwt. q. lb.
1	No manure	42.5	49.9	54	28 3 18
2	Complete Artificials: Superphosphate 3 cwt., Sul/Potash ½ cwt., Sul/Ammonia 1 cwt.	44.7	48.9	65	26 3 0
3	Superphosphate 3 cwt., Sulphate of Potash 1½ cwt.	45.0	47.1	66	31 2 10
4	Superphosphate 3 cwt., Sulphate of Ammonia 1 cwt.	41.8	48.4	62	29 0 4
5	Sulphate of Potash 1½ cwt., Sulphate of Ammonia 1 cwt.	39.9	49.1	50	29 0 8

The differences between the plots were but small, and, the unmanured produce itself reaching 42½ bushels per acre, showed that the land was a good deal richer than had been expected, and that it really needed no more manuring.

(*b*) Great Hill.

Simultaneously with the foregoing, an experiment on an adjoining field of light sandy soil, but entirely on the Lower Greensand formation, was carried out. A light crop of swedes had been fed on this land by sheep, receiving also a little cotton cake. It was desired to see whether mineral superphosphate given in addition proved an advantage to the following barley crop.

Two plots of ½-acre were marked out, and to one of them superphosphate at the rate of 3 cwt. per acre was given previous to the drilling of barley ("Plumage Archer") on April 25th.

The crop was cut on September 16th, 1922, and threshed on January 24th, 1923.

The results were :—

Malting Barley Experiments (Great Hill), *1922.*

Produce of Barley per acre, after Swedes fed off by Sheep.

Plot	Manures	Head Corn		Tail Corn	Straw, Chaff, etc.
		Bushels	Weight per bushel	Weight	
			lb.	lb.	cwt. q. lb.
1	With Superphosphate . .	34.6	51.5	99	16 3 15
2	Without Superphosphate .	38.4	51.1	69	17 1 11

On this lighter soil the crop was lower than on Warren Field, but was by no means a bad one for the land. The straw, however, was much shorter, and only about half the yield of Warren Field. The addition of superphosphate did not appear to have increased the yield either of corn or of straw.

7. *Experiments with Potassic Fertilisers* (*Sulphate and Muriate*) *on Potatoes.*

In 1922, experiments were carried out at Woburn, in common with other centres, for the purpose of testing the respective influence of sulphate of potash and muriate of potash, on the yield, quality, etc., of potatoes. The field selected at Woburn was Lansome Field, and the variety "Kerr's Pink," the seed having been obtained direct from Perthshire.

The soil is a light sandy loam, very suitable for the growth of potatoes. Spraying with *Bouillie Bordelaise* was carried out on September 1st and 2nd, and a second time on September 20th, though there was but little appearance of disease. It was noticed during growth that the plots treated with muriate of potash were lighter in colour than those with sulphate of potash, and also that the tops were bigger where no farmyard manure had been given.

The lifting of the crop began on November 15th when the crops were weighed, and the returns are shown on page 69. In this table the weights are recorded as taken when the crop was lifted, whereas the separation into "ware," "seed," and "diseased" was not made until several months later when the potatoes were actually sold. Owing to difficulties in disposing of

Experiments with Potassic Fertilisers on Potatoes
(LANSOME FIELD), *1922.*

Produce per acre.

Plot.	Manuring per acre.	Kerr's Pink. Weight per acre.			
	Series A *with* Farmyard Manure 12 tons.	T.	c.	q.	lb.
1	Superphosphate 4 cwt. + 1½ cwt. Sulph. Potash	12	2	0	0
3	Sulph. Ammonia 1½ cwt. + 1½ cwt. Sulph. Potash	12	10	1	20
2	Superphosphate 4 cwt. + equivalent in Muriate of Potash	13	14	0	16
4	Sulph. Ammonia 1½ cwt. + equivalent in Muriate of Potash	12	1	3	16
	Series B *without* Farmyard Manure.				
5	Superphosphate 6 cwt. + 1½ cwt. Sulph. Potash	13	8	2	12
7	Sulph. Ammonia 2 cwt. + 1½ cwt. Sulph. Potash	13	8	1	24
6	Superphosphate 6 cwt. + equivalent in Muriate of Potash	13	13	0	12
8	Sulph. Ammonia 2 cwt. + equivalent in Muriate of Potash	13	19	1	12

the crop, the actual removal from the heaps and sale only began in the middle of March, 1922, and continued till the close of May. Hence a division of the crop into the three sections would give no fair comparison, as the shrinkage in weight owing to storage, sprouting, etc., would vary with the time of keeping.

It may, however, be said that there was, on the average, no difference between sulphate of potash and muriate of potash either in respect of "seed"—which worked out at 7%—or of "diseased"—which did not exceed 1%.

The duplicates, with the exception of plots 2 and 4, agreed very fairly. Muriate of potash gave, on the average, 10 cwt. per acre more yield than did the same amount of potash as sulphate. Also the yield was 1 ton per acre more where, in place of farmyard manure, additional superphosphate and sulphate of ammonia were used.

The crop all round was a splendid one; it gave but few diseased tubers, and, after being pitted, it kept well throughout the winter and right on to May, 1923.

POT-CULTURE EXPERIMENTS, 1922.

Though the transference to Cambridge of the work hitherto done at Woburn under the terms of the Hills' bequest, brought to an end my official connection with this, yet the experience I had derived during a period of 25 years, and the interest I felt in the methods of enquiry pursued, determined me to carry on the experiments so far as I found this possible. Similarly, the many enquiries that had been initiated and were still in progress in connection with the Woburn field experiments rendered it desirable that these, too, should be continued. This I have succeeded in doing, and the present is an account of the work carried on in 1921-22.

I. *The Hills' Experiments.*

These—if I may be allowed still to apply the term to them—embraced in 1922 :—

(*a*) The action of compounds of Lead on wheat.

(*b*) The action of Chromium compounds on wheat.

(*a*) Lead Compounds.

In previous work in 1912 (Journal R.A.S.E., 1912, pp. 324-5) it was found that lead salts, when present to the extent of .03% of lead in the soil, exerted no harmful influence in the case of the phosphate, nitrate or carbonate. In 1914 (Journal R.A.S.E., 1914, pp. 312-3) the same salts, but in higher amount (up to .10% of lead), and with the sulphate and chloride additionally tried, similarly failed to show any injurious effect. The subject was then left for a time, but I returned to it now, taking still higher amounts of the metal and using the following compounds of lead, the oxide (litharge), carbonate, sulphate and chloride. The quantities now employed were respectively .25%, .50% and 1% of the metal. The salts were mixed with the whole of the soil in each pot, and each experiment was, as usual, in duplicate, the soil being that from Stackyard Field.

Wheat was sown on December 20th, 1921, and nothing was noticeable with regard to germination except in the case of the lead chloride sets. In these .25% slightly retarded germination, .50% still more so, and 1% very markedly. The full number of plants did not come up in any of these.

The only differences between the crops, and only signs of any toxic influence were with the chloride; with this, .25% did not appear to do any harm, but with .50% there were only one or two weakly plants left, while with 1% the few plants that came up at first died away entirely.

Plate I. shows the appearances very clearly, and the comparative weights in the case of the chloride are given below.

Lead Chloride upon Wheat, 1922.

Treatment		Corn	Straw
Untreated		100	100
Lead Chloride . . .	.25% Lead	136.3	116.1
Lead Chloride . . .	.50% Lead	—	—
Lead Chloride . . .	1% Lead	—	—

From this experiment it would result that lead present as chloride in a soil will produce a toxic effect as soon as the quantity exceeds .25% of lead, but that in the forms of the oxide, carbonate and sulphate, no harmful influence is exercised up to 1% of lead.

(*b*) Chromium Compounds on Wheat.

1.—The experiments of 1920 and 1921 with chromate and bichromate of potash were continued for a third year, the same pots without alteration or addition being used again for a third corn crop which was sown on October 27th, 1921.

By way of recapitulation, it may be said that in the first year

A B C D E F G

PLATE I.—LEAD COMPOUNDS UPON WHEAT, 1922.

(*a*) Untreated; (*b*) 1 per cent. Lead as Oxide; (*c*) 1 per cent. Lead as Carbonate; (*d*) 1 per cent. Lead as Sulphate; (*e*) ·25 per cent. Lead as Chloride; (*f*) ·50 per cent. Lead as Chloride; (*g*) 1 per cent. Lead as Chloride.

.025%, .01% and .005% of chromium were shown to be fatal to barley, whether chromate or bichromate was used, and that in the second year only the .025% proved still harmful to wheat, any injurious effect from .01% and .005% having passed off. Now in the third year, wheat being again sown, the .025% also lost its ill effect, and exercised, as did the lower amounts, a slightly stimulating influence.

2.—The fresh experiments started in 1921 with chromate and bichromate of potash, and also with chromic acid, were continued in 1922 with a second wheat crop. In 1921 it had been found that .005% of chromium was not a safe amount to use, whether as chromate or bichromate of potash or as chromic acid, but that smaller amounts of .0025% and .001% exercised a decidedly stimulating influence. On continuing, without further additions, for a second wheat crop in 1922, the results showed that a marked increase of crop was obtained from the .005% application (which the year before had been destructive), and a like, but decreasing, benefit from the smaller applications.

Putting together the results of 1 and 2 as here described, the general conclusion is reached that, while .005% of chromium is not a safe amount to have in a soil for the first year of growth of a corn crop, smaller quantities will not prove harmful, but rather stimulating, and that .005%, and even .01%, will lose its injurious effect in a second year, and .025% in a third year, a stimulating influence taking then the place of a previously harmful one.

The changes shown in the first 2 years may be illustrated by the accompanying curves obtained with potassium bichromate.

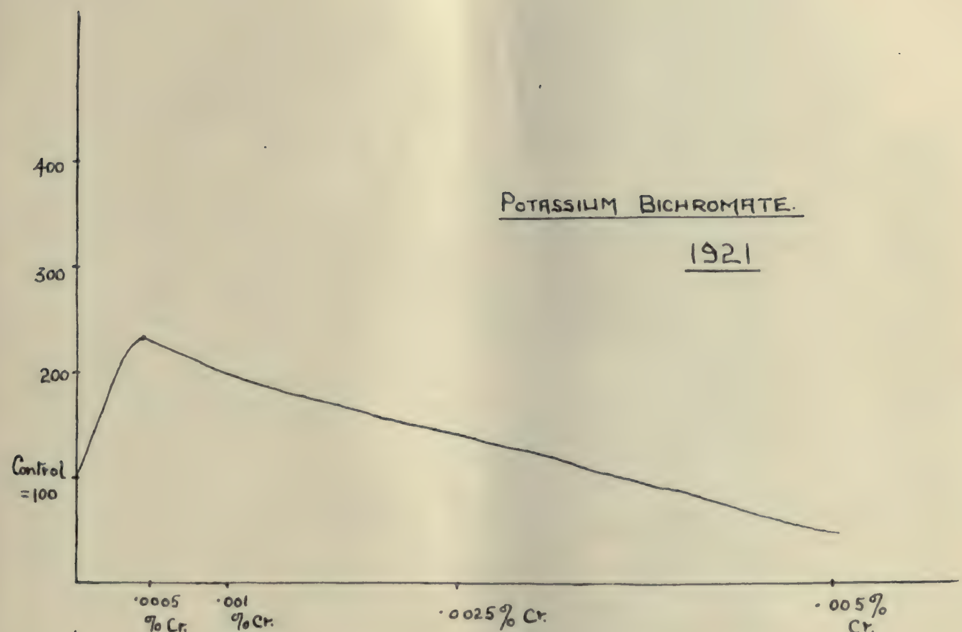
II. *The Relative Effects of Lime and Chalk, 1922.*

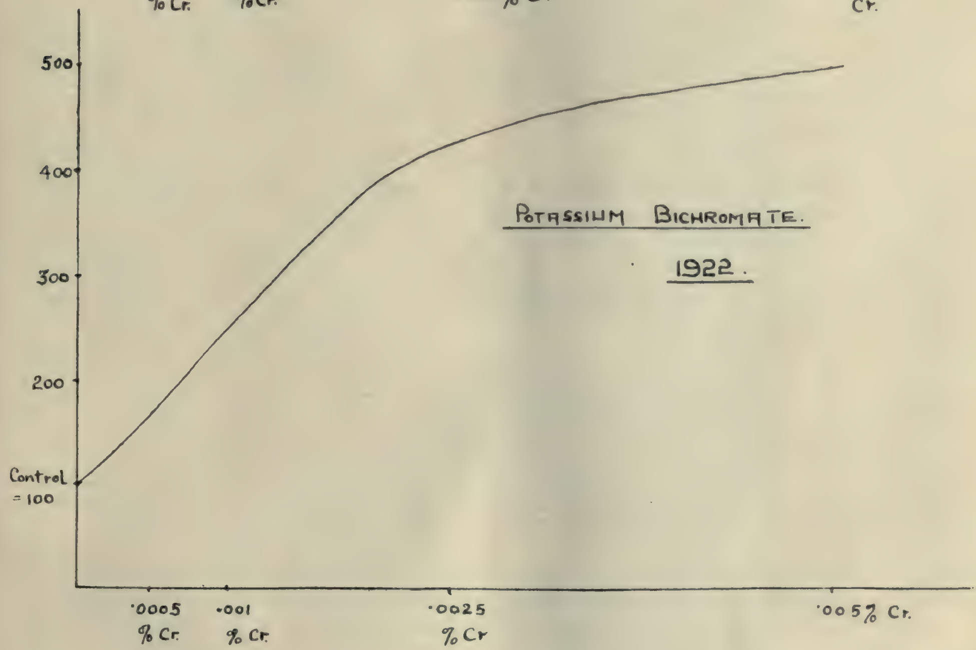
This experiment, a duplicate, in pot-culture, of the field experiment in Stackyard Field (Series B) started in 1919, was continued for a fourth year, no further additions being given, and wheat being sown again on October 26th, 1921.

Lime, it may be recalled, was given at the rates of 10 cwt., 1 ton, 2 tons, 3 tons, and 4 tons per acre respectively, and chalk to supply the same amounts of lime (CaO). The results obtained were very similar to those of 1920, and in the following table the figures for the 4 years are collected.

Lime and Chalk upon Wheat.

Treatment	1919 Barley		1920 Wheat		1921 Wheat		1922 Wheat		Average of 4 Years	
	Corn	Straw	Corn	Straw	Corn	Straw	Corn	Straw	Corn	Straw
No Lime	100	100	100	100	100	100	100	100	100	100
Lime (CaO) 10 cwt. per acre	120	116	117	107	128	108	98	113	116	111
,, ,, 1 ton ,, ,,	144	165	124	112	161	138	129	118	140	133
,, ,, 2 tons ,, ,,	233	245	131	112	195	150	133	119	173	156
,, ,, 3 ,, ,, ,,	293	292	150	132	217	151	133	119	198	173
,, ,, 4 ,, ,, ,,	299	314	149	126	264	176	149	129	215	186
No Lime	100	100	100	100	100	100	100	100	100	100
Chalk = CaO 10 cwt. per acre	98	103	107	96	106	99	108	103	105	100
,, ,, 1 ton ,, ,,	113	109	127	111	130	101	127	110	124	108
,, ,, 2 tons ,, ,,	113	114	116	105	148	123	132	123	127	116
,, ,, 3 ,, ,, ,,	124	114	106	107	153	145	111	112	123	119
,, ,, 4 ,, ,, ,,	106	111	119	92	153	124	119	122	124	112


POTASSIUM BICHROMATE.
1921
400
300
200
Control =100
·0005 % Cr.
·001 % Cr.
·0025 % Cr.
·005 % Cr.


POTASSIUM BICHROMATE.
1922.
500
400
300
200
Control =100
·0005 % Cr.
·001 % Cr.
·0025 % Cr
·005 % Cr.

With lime—as caustic lime—there was thus a progressive increase as more lime was used, right up to 4 tons per acre, the increase being shown most the first and third years; with chalk, however, though there was a slight increase, it was a much smaller one and not a regularly increasing one with the amount applied. It can, therefore, be hardly maintained that lime and chalk act similarly in the soil, or that it is immaterial whether one or the other be used, so long as the same amount of lime (CaO) is applied. In the present instance the soil was one notably deficient in lime, and here, at all events, the caustic lime has proved markedly more effective. As noted in the last report (Journal R.A.S.E., 1921, pp. 290-1) this experiment raises several important questions, *e.g.*, whether lime retains its causticity longer than is generally believed to be the case, or whether it becomes converted into silicate of lime or other forms in which it continues to have a marked effect. That it does not merely become changed straightway into carbonate of lime (as is generally supposed), and acts in the same way as chalk, would seem to be abundantly disproved by this 4 years' work. Were this the case, there is no reason why the results with chalk should not have been equal to those of caustic lime. As the outcome of this enquiry, I am convinced that the method commonly adopted of estimating the lime requirements of a soil by determining only the amount of lime present as carbonate of lime is incorrect.

III. *The Influence of Fluorides on Wheat, 1922* (2nd Year).

The experiments of 1921 were continued for a second year, no further additions being given, but wheat was again sown on October 27th, 1921.

It may be repeated here that the 1921 experiments showed a decidedly stimulating influence exercised by potassium fluoride used in quantity containing .05 and .1% of fluorine respectively, but that with sodium fluoride a complete alteration of the condition of the soil took place, this becoming hard and caked on the surface, very impervious to water, and dark in colour. Further, while the smaller amount of sodium fluoride (.05% fluorine) affected germination and killed a number of the plants, the few that survived grew most vigorously. With the higher amount (.1% fluorine) though a few plants came up, they were all eventually killed off. Potassium fluoride showed none of these changes in the soil, nor harm to the crop.

In the second year the germination with sodium fluoride was hardly affected by the smaller amount (.05% fluorine), but was markedly so with the higher quantity (.10%). Much the same general results were obtained as in 1921, except that the lower quantity of sodium fluoride did not kill off the plants, but produced a stimulating effect on them. The higher amount (.10% fluorine), however, as in 1921, killed everything off.

The appearances are shown in Plate II, and the comparative results are given in the following table:—

A B C D E F G

PLATE II.—FLUORIDES UPON WHEAT, 1922.

(*a*) Untreated; (*b*) Calcium Fluoride 5 cwt. per acre; (*c*) Potassium Fluoride, giving ·1 per cent. Fluorine to soil; (*d*) Potassium Fluoride, giving ·05 per cent. Fluorine to soil; (*e*) Sodium Fluoride, giving ·1 per cent. Fluorine to soil; (*f*) Sodium Fluoride, giving ·05 per cent. Fluorine to soil; (*g*) Calcium Silico-Fluoride, 5 cwt. per acre.

Fluorides on Wheat, 1922.

Treatment.	Corn	Straw
Untreated	100	100
Calcium fluoride 5 cwt. per acre	170.3	139.5
Potassium fluoride containing .1 per cent. Fl.	470	262
,, ,, ,, .05 ,, ,,	451	244
Sodium fluoride ,, .1 ,, ,,	—	—
,, ,, ,, .05 ,, ,,	292	202
Calcium-silico-fluoride 5 cwt. per acre	55.4	76

IV. *The Influence of Silicates on Wheat, 1922* (3rd Year).

The experiments of 1920 and 1921 were carried a further stage, no further additions being given, but wheat being sown again in the pots on December 21st, 1921. The previous years had shown calcium silicate to give an increase in the crop as the amount of it was increased, and this up to an application of 4 tons per acre, the increase being more marked the second than the first year. On the other hand, kaolin produced no effect, and magnesium silicate a less marked one than calcium silicate.

The 1922 results were of similar nature, showing a continued benefit from calcium silicate, increasing as more was used, while that of magnesium silicate was, on the whole, less.

The three years' results follow :—

Silicates upon Wheat, 1920-2.

Treatment	1920		1921		1922	
	Corn	Straw	Corn	Straw	Corn	Straw
Untreated	100	100	100	100	100	100
Calcium silicate, 1 ton per acre	113.4	104.1	146	126	128	107
,, ,, 2 tons ,, ,,	124.4	116.8	187	136	150	117
,, ,, 4 ,, ,, ,,	150.1	139.0	226	159	197	140
Magnesium silicate, 1 ton per acre	111.9	115.1	96	115	97	101
,, ,, 2 tons ,, ,,	109.5	124.5	149	135	168	110
,, ,, 4 ,, ,, ,,	113.5	135 4	172	139	179	123
Kaolin, 1 ton per acre	83.8	104.3	68.5	83	70	81.5
,, 2 tons ,, ,,	96.5	100.3	?	77.5	76	71
,, 4 ,, ,, ,,	103.0	96.8	108	98.5	98	102

From this it would appear to be clearly established that calcium silicate is a far from inactive form of lime, and that this may have a bearing upon the experiments recorded under II. in this section, as regards the relative efficiency of lime and chalk.

DATES OF SOWING AND HARVESTING (Harvest 1921).

Field.	Crop.	Variety.	Sowing began.	Sowing finished.	Cutting began.	Carting began.	Carting finished.	Yield per Acre.
Great Knott, east ...	Oats	Grey Winter	Oct. 6, '20	Oct. 9, '20	July 14	July 21	July 23	44 bush.
,, west ...	Clover	Broad Red	Apr. 26, '20	Apr. 27, '20	June 13	June 21	June 23	21·5 cwt.
Little Knott	Grass Ley (3rd yr.)	Mixture...	Apr. 8, '18	Apr. 10, '18	June 28	June 30	July 1	17·0 cwt.
Fosters, east	Oats	Grey Winter	Oct. 9, '20	Oct. 14, '20	July 15	July 25	July 25	41·7 bush.
,, west	Oats ... ... Barley	Grey Winter mended with Plumage Archer	Mar. 14, '21	Mar 14, '21	July 29	Aug. 5	Aug. 5	33 bush.
West Barnfield	Clover	Broad Red	Apr. 26, '20	Apr. 26, '20	June 9	June 15	June 15	31·3 cwt.
Long Hoos, east ...	Wheat	Red Standard ... ... Danish Svalof	Nov. 9, '20	Nov. 11, '20	July 28	Aug. 6	Aug. 9	30·2 bush.
,, west ...	Wheat	Red Standard ... ... Swedish Iron ... . Marshall Foch	Oct. 21, '20	Oct. 23, '20	July 30	Aug. 6	Aug. 9	
Great Harpenden ...	Wheat	Red Standard	Oct. 15, '20	Oct. 20, '20	July 26	Aug. 2	Aug. 3	22 bush.
New Zealand	Wheat	Red Standard	Nov. 6, '20	Nov. 9, '20	July 27	Aug. 4	Aug. 4	30·2 bush.
Stackyard	Barley	Plumage Archer	Mar. 11, '21	Mar. 30, '21	Aug. 3	Aug. 12	Aug. 12	35·5 bush.
Sawpit	Potatoes	Arran Chief	Apr. 8, '21	Apr. 11, '21	...	Sept. 26	Oct. 10	1·5 tons ware
		Kerr's Pink	Apr. 12, '21	Apr. 13, '21	...	Oct. 30	Nov. 5	1·1 ,, small
Broadbalk	Wheat	Red Standard	Nov. 4, '20	Nov. 5, '20	July 27	Aug. 9	Aug. 10	see p. 85
Little Hoos	Barley	Plumage Archer	Mar. 9, '21	Mar. 9, '21	Aug. 4	Aug. 12	Aug. 12	,, 90
Hoos	Barley	Plumage Archer	Feb. 19, '21	Feb. 21, '21	July 30	Aug. 11	Aug. 11	,, 89
	Wheat	Red Standard	Nov. 5, '20	Nov. 5, 20'	July 28	Aug. 10	Aug. 10	see pp. 87 and 88
Barnfield	Mangolds ...	Prizewinner Yellow Globe ...	Apr. 27, '21	Apr. 27, '21	...	Nov. 15	Dec. 2	see p. 81
Agdell	Barley	Plumage Archer	Feb. 23, '21	Feb. 23, '21	Aug. 5	Aug. 12	Aug. 12	,, 79
Great Field	Pasture	— —	... ...	... ...	... ...	... ...	... ...	...
Park	Hay	— —	... ...	... ...	June 23	June 27	June 28	see p. 82

DATES OF SOWING AND HARVESTING (Harvest 1922).

Field.	Crop.	Variety.	Sowing began.	Sowing finished.	Cutting began.	Carting began.	Carting finished.	Yield per Acre.
Great Knott, east ...	Wheat	Red Standard	Oct. 24, '21	Oct. 26, '21	Aug. 29	Sept. 11	Sept. 21	18 bush.
,, west ...	Clover	Red	Apr. 26, '20	Apr. 27, '20	June 9	not	carted	
Little Knott	Grass Ley (4th yr.)	Mixed	Apr. 8, '18	Apr. 10, '18	June 17	June 20	June 23	11 cwt.
Foster's, east	Wheat	Red Standard	Oct. 24, '21	Oct. 26, '21	Aug. 24	Sept. 6	Sept. 7	16 bush.
,, west	Wheat	Red Standard						
West Barnfield	Clover	Red	Apr. 26, '20	Apr. 26, '20	June 16	June 21	June 22	12 cwt.
Long Hoos, east ...	Oats	Grey Winter	Sept. 24, '21	Sept. 26, '21	Aug. 2	Aug. 16	Aug. 18	48 bush.
,, west ...	Barley	Plumage Archer	Mar. 30, '22	Apr. 1, '22	Sept. 12	Sept. 29	Sept. 30	33 bush.
Great Harpenden ...	Mangolds ...	Prizewinner Yellow Globe ...	May 2, '22	May 12, '22	... ...	Oct. 25	Nov. 22	19¾ tons.
	Potatoes	Kerr's Pink	Apr. 22 '22	Apr. 24, '22	... ...	Oct. 10	Oct. 26	see pp. 94 and 98
	Swedes	Hurst's Monarch	May 19, '22	May 26, '22	... ...	Oct. 4	Nov. 14	27½ tons.
New Zealand	Wheat	Red Standard	Nov. 10, '21	Nov. 11, '21	Sept. 4	Sept. 21	Sept. 26	28 bush.
Stackyard	Barley	Plumage Archer	Mar. 25, '22	Mar. 28, '22	Sept. 5	Sept. 22	Oct. 3	33 bush.
Sawpit	Wheat	Red Standard	Oct. 18, '21	Dec. 8, '21	Aug. 23	Sept. 2	Sept. 16	24 bush.
Sawyers	Vetches and Oats mixed ...	Winter Vetches ... ... Grey Winter Oats	Sept. 17, '21	Sept. 19, '21	Aug. 5	Sept. 8	Sept. 9	7½ bush. 8 bush.
Broadbalk	Wheat	Red Standard	Oct. 28, '21	Oct. 28, '21	Aug. 29	Sept. 18	Sept. 20	see p. 86
Little Hoos	Barley	Plumage Archer	Mar. 25, '22	Mar. 25, '22	Sept. 7	Sept. 21	Sept. 23	,, 90
Hoos	Barley	Plumage Archer	Mar. 18, '22	Mar. 18, '22	Sept. 6	Sept. 25	Sept. 26	,, 89
	Wheat	Red Standard	Oct. 29, '21	Oct. 29, '21	Sept. 6	Sept. 26	Sept. 26	,, 87
Barnfield	Mangolds ...	Prizewinner Yellow Globe ...	May 1, '22	May 1, '22	... ...	Nov. 1	Nov. 9	,, 81
Agdell	Clover	Red	Apr. 21, '21	Apr. 22, '21	June 21	July 12	July 12	,, 79
Great Field	Hay	— —	... ...	... ...	June 22	June 30	July 1	,, 95
Park	Hay	1st Crop	... ...	... ...	June 26	July 1	July 10	,, 82
		2nd Crop	... ...	... ...	Oct. 5	Oct. 16	Oct. 17	,, 82

CROP YIELDS ON THE EXPERIMENTAL PLOTS

NOTES.—In each case the year refers to the harvest, *e.g.*, Wheat harvested in 1921. In the tables, total straw includes straw, cavings and chaff. In previous reports the figures for total straw only have been given.

CONVERSION TABLE

1 acre	=	0·404 Hectare	0·963 Feddan.
1 bushel (Imperial)	=	0·346 Hectolitre (36·346 litres) ...	0·184 Ardeb.
1 lb. (pound avoirdupois)	=	0·453 Kilogramme	1·009 Rotls.
1 cwt. (hundredweight)	=	50·8 Kilogrammes	113·0 Rotls. 1·366 Maunds
1 metric quintal ...	=	100·0 Kilogrammes ... ... 220·46 lb.	
1 bushel per acre ...	=	0·9 Hectolitre per Hectare ...	0·191 Ardeb per Feddan.
1 lb. per acre ...	=	1·12 Kilogramme per Hectare ...	1·049 Rotls per Feddan.
1 cwt. per acre ...	=	125·60 Kilogrammes per Hectare or 1·256 metric Quintals per Hectare	117·4 Rotls per Feddan.

In America the Winchester bushel is used = 35·236 litres. 1 English bushel = 1·032 American bushels.

CROPS GROWN IN ROTATION. AGDELL FIELD.

PRODUCE PER ACRE.

Year.	CROP.	O. Unmanured.		M. Mineral Manure.		C. Complete Mineral and Nitrogenous Manure.	
		5. Fallow.	6. Clover or Beans.	3. Fallow.	4. Clover or Beans.	1. Fallow.	2. Clover or Beans.
	AVERAGE OF THE FIRST EIGHTEEN COURSES, 1848-1919.						
	Roots (Swedes) cwt.*	33·4	11·8	176·4	191·3	360·7	317·4
	Barley—						
	Dressed Grain bush.	23·3	21·9	24·4	24·4	33·4	37·5
	Total Straw ... cwt.	14·1	14·0	14·3	16·1	20·2	22·9
	Beans—						
	Dressed Grain bush.	—	13·1	—	18·2	—	22·3
	Total Straw ... cwt.	—	9·2	—	13·2	—	15·3
	Clover Hay ... cwt.	—	30·7	—	58·6	—	60·2
	Wheat—						
	Dressed Grain bush.	24·6	22·7	29·0	31·4	30·1	31·6
	Total Straw ... cwt.	23·9	21·4	29·1	30·3	31·8	30·7
	PRESENT COURSE (19th), 1920-22.						
1920	Roots (Swedes) ... cwt.	20·5	2·1	163·9	270·0	262·1	56·4‡
1921	Barley—						
	Dressed Grain bush.	13·0	2·4†	12·8	26·3	10·9	25·7
	Offal Grain ... lb.	57·0	42·0	45·0	58.0	39·0	65·0
	Straw ... ... lb.	891·0	601·0	596·0	1124·0	444·0	1444·0
	Total Straw ... cwt.	10·9	7·8	7·9	14·2	6·3	17·7
	Wght. of Dressed Grain per bush. lb.	55·1	51·0	56·5	56·8	56·4	56·7
	Proportion of Total Grain to 100 of Total Straw	63·0	19·0	86·3	97·5	92·2	77·1
1922	Clover Hay ... cwt. (1 crop only)	—	4·4	—	9·7	—	3·5

* Plots 1, 3 and 5 based upon 17 years. Plots 2, 4 and 6 based upon 16 years.
† Plot 6 was more badly attacked by Gout Fly than the other plots.
‡ The roots on this plot were badly attacked by finger and toe disease in 1920.
In 1920 Rape Cake was omitted from plots 1 and 2.

METEOROLOGICAL RECORDS, 1921 and 1922.

	Rain.		Drainage through soil.				Temperature (Mean).				
	Total Fall. $\frac{1}{1000}$ Acre Gauge.	No. of Rainy Days. (0·01 inch or more) $\frac{1}{1000}$ Acre Gauge.	20 ins. deep.	40 ins. deep.	60 ins. deep.	Bright Sunshine.	Max.	Min.	1 ft. in ground.	Solar Max.	Grass Min.
1921	Inches.	No.	Inches.	Inches.	Inches.	Hours.	°F.	°F.	°F.	°F.	°F.
Jan. ...	2·452	18	2·103	2·202	2·087	42·9	48·8	39·7	42·8	69·7	35·5
Feb. ...	0·214	7	0·016	0·068	0·053	77·9	45·2	34·0	39·6	78·9	27·8
Mar. ...	1·065	12	0·005	0·028	0·028	132·1	51·8	36·4	43·0	99·5	29·6
April ...	1·568	10	0·114	0·120	0·110	195·7	55·2	37·3	46·1	111·1	30·7
May ...	1·445	14	0·065	0·113	0·120	228·8	62·0	43·3	53·7	122·7	36·0
June ...	0·194	2	—	0·005	0·009	216·0	67·4	47·5	59·1	125·4	41·6
July ...	0·179	5	—	0·003	0·006	240·0	76·8	53·4	64·9	132·1	47·1
Aug. ...	1·113	10	—	—	—	145·2	69·2	52·7	61·9	122·8	48·5
Sept. ...	2·733	6	0·925	0·893	0·850	174·0	67·6	49·0	58·4	114·8	43·5
Oct. ...	0·787	8	—	—	—	154·2	63·6	46·4	54·0	106·6	40·5
Nov. ...	2·435	11	0·969	0·966	0·796	68·9	43·9	33·3	42·6	69·2	28·3
Dec. ...	1·908	16	1·569	1·586	1·420	47·3	47·9	36·7	41·8	67·1	32·8
Total or Mean	16·093	119	5·766	5·984	5·479	1723·0	58·3	42·5	50·7	101·7	36·8
1922											
Jan. ...	3·148	21	2·811	2·862	2·638	53·7	43·5	32·7	38·5	65·7	28·6
Feb. ...	2·507	16	1·734	1·718	1·612	104·9	44·9	33·6	38·2	76·1	28·6
Mar. ...	2·285	14	1·349	1·477	1·406	113·5	45·2	34·8	40·9	89·8	30·1
April ...	3·520	19	1·458	1·535	1·390	149·8	48·7	34·7	41·8	105·7	29·2
May ...	1·579	7	0·144	0·224	0·235	280·2	65·4	45·0	53·1	120·8	37·2
June ...	1·038	8	—	0·016	0·022	228·8	65·9	48·1	59·8	121·6	41·2
July ...	4·605	19	1·661	1·748	1·599	149·5	63·7	49·7	57·8	120·4	43·6
Aug. ...	2·930	16	0·675	0·698	0·651	127·3	63·2	49·2	57·9	117·8	42·8
Sept. ...	2·882	15	1·085	1·111	1·010	102·6	60·5	46·3	54·8	110·2	40·5
Oct. ...	0·764	13	0·175	0·194	0·159	140·0	52·8	40·0	48·4	99·7	33·5
Nov. ...	1·433	8	0·813	0·854	0·751	56·8	47·0	34·7	41·5	71·3	28·4
Dec. ...	3·091	18	2·719	2·741	2·572	55·5	45·4	36·3	40·5	66·6	30·9
Total or Mean	29·782	174	14·624	15·178	14·045	1562·6	53·9	40·4	47·8	97·1	34·6

RAIN AND DRAINAGE.

MONTHLY MEAN FOR 52 HARVEST YEARS, 1870-1—1921-2.

	Rainfall.	Drainage.			Drainage % of Rainfall.			Evaporation.		
		20-in. Gauge	40-in. Gauge	60-in. Gauge	20-in. Gauge	40-in. Gauge	60-in. Gauge	20-in. Gauge	40-in. Gauge	60-in. Gauge
	Ins.	Ins.	Ins.	Ins.				Ins.	Ins.	Ins.
September	2·334	0·751	0·714	0·655	32·2	30·6	28·1	1·583	1·620	1·679
October ...	3·153	1·788	1·742	1·617	56·7	55·2	51·3	1·365	1·411	1·536
November	2·769	2·095	2·127	2·006	75·7	76·8	72·4	0·674	0·642	0·763
December	2·845	2·417	2·505	2·393	84·9	88·0	84·1	0·428	0·340	0·452
January...	2·381	1·914	2·096	2·015	80·4	88·0	84·6	0·467	0·285	0·366
February	1·983	1·457	1·558	1·487	73·5	78·6	75·0	0·526	0·425	0·496
March ...	2·086	1·130	1·264	1·195	54·2	60·6	57·3	0·956	0·822	0·891
April ...	2·032	0·658	0·731	0·697	32·4	36·0	34·3	1·374	1·301	1·335
May ...	2·006	0·461	0·523	0·489	23·0	26·1	24·4	1·545	1·483	1·517
June ...	2·307	0·572	0·592	0·572	24·8	25·7	24·8	1·735	1·715	1·735
July ...	2·656	0·685	0·710	0·659	25·8	26·7	24·8	1·971	1·946	1·997
August ...	2·693	0·725	0·726	0·683	26·9	27·0	25·4	1·968	1·967	2·010
Year ...	29·245	14·653	15·288	14·468	50·1	52·3	49·5	14·592	13·957	14·777

Area of each gauge $\frac{1}{1000}$th acre.

MANGOLDS, BARN FIELD, 1921 and 1922.

Roots since 1856. Mangolds since 1876.

Produce per Acre.

Strip.	Strip Manures.		Cross Dressings.			
		O. None.	N. Nitrate of Soda	A. Ammon. Salts.	A.C. Ammon. Salts and Rape Cake.	C. Rape Cake.
	1921.	Tons.	Tons.	Tons.	Tons.	Tons.
1	Dung only	R. **16·25**	**24·82**	**15·50**	**13·71**	**17·44**
		L. 2·46	3·56	2·49	2·62	3·12
2	Dung, Super., Potash ...	R. **22·60**	**31·01**	**25·44**	**25·20**	**25·75**
		L. 3·42	4·99	4·95	5·33	4·68
4	Complete Minerals ...	R. **6·07**	a R. **19·18*** L. 4·63	**14·62**	**23·27**	**16·69**
		L. 1·11	b R. **16·08** L. 4·30	3·41	5·03	3·50
5	Superphosphate only ...	R. **5·36**	**12·35**	**3·57**	**3·19**	**4·43**
		L. 1·07	3·14	1·69	1·54	1·66
6	Super. and Potash ...	R. **5·46**	**17·20**	**13·58**	**18·37**	**14·04**
		L. 1·27	4·03	3·54	4·38	3·31
7	Super., Sulphate of Mag., and Sodium Chloride	R. **5·74**	**18·33**	**13·94**	**14·37**	**13·24**
		L. 1·33	4·29	3·20	4·45	3·56
8	None	R. **3·60**	**7·53**	**2·57**	**2·87**	**1·20**
		L. 1·07	3·02	1·63	1·53	1·34
9	Sodium Chloride, Nit. Soda, Sulph. Potash, and Sulph. Mag. ...	R. **20·15**				
		L. 4·53				
	1922†.					
1	Dung only	R. **14·90**	**18·54**	**14·25**	**26·37**	**26·11**
		L. 3·35	3·98	3·52	5·57	5·46
2	Dung, Super., Potash ...	R. **18·15**	**12·46**	**9·29**	**31·55**	**30·35**
		L. 3·51	2·67	2·20	6·34	5·40
4	Complete Minerals ...	R. **3·32**	a R. **2·27*** L. 0·80	**0·54**	**28·46**	**21·89**
		L. 0·95	b R. **2·49** L. 0·83	0·25	5·34	3·49
5	Superphosphate only ...	R. **1·90**	**3·38**	**0·35**	**10·53**	**11·39**
		L. 0·66	1·06	0·16	3·67	4·00
6	Super. and Potash ...	R. **2·28**	**3·64**	**0·67**	**21·96**	**19·56**
		L. 0·80	1·13	0·30	5·55	3·73
7	Super., Sulphate of Mag., and Sodium Chloride	R. **2·13**	**2·65**	**0·67**	**18·45**	**18·97**
		L. 0·79	0·85	0·33	5·12	3·81
8	None	R. **1·72**	**0·93**	**0·40**	**6·98**	**7·65**
		L. 0·69	0·49	0·22	2·95	3·13
9	Sodium Chloride, Nit. Soda, Sulph. Potash and Sulph. Mag. ...	R. **2·89**				
		L. 1·04				

R.=roots. L.=leaves.

* From 1904 onwards plot 4 N has been divided, 4*a* receiving Sulphate of Potash, Sulphate of Magnesia, Sodium Chloride and Nitrate of Soda; 4*b* receiving Calcium Chloride, Potassium Nitrate and Calcium Nitrate.

† In 1922 the top dressings of Nitrate of Soda and Sulphate of Ammonia were omitted from plots 4—8 on series N and A as the plant had failed. The plant on Series A, N, O and plot 9, was badly attacked by *Atomaria* (pigmy mangold beetle).

HAY. THE PARK GRASS PLOTS. 1921, 1922.

Plot.	Manuring per acre.		1921. Yield of Hay per acre.	1921. Dry Matter per acre.	1922. Yield of Hay per acre. 1st Crop.	1922. Yield of Hay per acre. 2nd Crop.	1922. Yield of Hay per acre. Total.	1922. Dry Matter per acre. 1st Crop.	1922. Dry Matter per acre. 2nd Crop.	1922. Dry Matter per acre. Total.	Plot.
			cwt.	lb.	cwt.	cwt.	cwt.	lb.	lb.	lb.	
1	Single dressing Amm. Salts (=43 lb. N.); (with Dung also 8 years 1856-63)	not limed	15·9	1474	9·7	29·2	38·9	650	2143	2793	1
		limed	18·5	1637	19·0	18·7	37·7	1255	1403	2658	
2	Unmanured; (after Dung 8 years, 1856-63)	not limed	11·4	991	16·7	16·5	33·2	1112	1213	2325	2
		limed	14·7	1227	18·3	15·2	33·5	1178	1047	2225	
3	Unmanured	not limed	8·8	727	14·8	13·1	27·9	952	1010	1962	3
		limed	10·3	839	12·4	11·7	24·1	816	787	1603	
4-1	Superphosphate of Lime	not limed	17·1	1398	19·6	13·9	33·5	1245	1058	2303	4-1
		limed	14·6	1199	15·0	13·1	28·1	995	910	1905	
4-2	Superphosphate of Lime and double dressing Amm. Salts (=86 lb. N.)	not limed	23·4	1866	2·3	11·9	14·2	154	839	993	4-2
		limed	23·7	2081	25·9	24·8	50·7	1805	1924	3729	
5-1	(N. half) Unmanured; following double dressing Amm. Salts (= 86 lb. N.) 1856-97	not limed	14·3	1125	4·6	8·2	12·8	296	638	934	5-1
5-2	(S. half) Super., Sulphate of Potash; following double dressing Amm. Salts (= 86 lb. N.) 1856-97	not limed	21·5	1955	11·3	12·0	23·3	811	919	1730	5-2
6	Complete Mineral Manure as plot 7; following double dressing Amm. Salts (= 86 lb. N.) 1856-68	not limed	27·9	2534	20·9	21·6	42·5	1420	1681	3101	6
7	Complete Mineral Manure	not limed	25·7	2376	23·4	23·4	46·8	1520	1605	3125	7
		limed	23·4	2088	21·2	17·4	38·6	1571	1359	2930	
8	Mineral Manure without Potash	not limed	21·0	1822	19·2	16·0	35·2	1209	1194	2403	8
		limed	14·0	1269	14·8	14·1	28·9	1056	1074	2130	
9	Complete Mineral Manure and double dressing Amm. Salts (= 86 lb. N.)	not limed	43·8	3887	7·5	33·9	41·4	483	2349	2832	9
		limed	52·7	4692	46·9	21·8	68·7	3652	1869	5521	
10	Mineral Manure (without Potash) and double dressing Amm. Salts (= 86 lb. N.)	not limed	35·2	3069	9·9	25·5	35·4	672	2028	2700	10
		limed	38·2	3510	32·6	19·2	51·8	2725	1543	4268	
11-1	Complete Mineral Manure and treble dressing Amm. Salts (=129 lb. N.)	not limed	65·9	5301	15·0	28·7	43·7	972	1935	2907	11-1
		limed	64·5	5494	55·3	27·6	82·9	4072	2398	6470	
11-2	As plot 11-1 and Silicate of Soda	not limed	63·6	5402	42·3	31·9	74·2	2832	2174	5006	11-2
		limed	57·1	5220	59·5	30·1	89·6	4525	2636	7161	

12	Unmanured	not limed	15·1	1355	17·7	12·1	29·8	1119	843	1962	12
13	Dung in 1905, and every fourth year since (omitted in 1917). Fish Guano in 1907 and every fourth year since	not limed	37·6	3408	41·5	23·1	64·6	2789	1835	4624	13
		limed ...	34·3	2994	26·7	18·5	45·2	2009	1361	3370	
14	Complete Mineral Manure and double dressing Nitrate of Soda (=86 lb. N.)	not limed	52·9	4348	49·8	25·4	75·2	3638	1745	5383	14
		limed	47·5	4061	39·7	18·6	58·3	2928	1086	4014	
15	Complete Mineral Manure as plot 7; following double dressing Nitrate of Soda (= 86 lb. N.)	not limed	23·6	2218	22·2	22·7	44·9	1519	1539	3058	15
		limed ...	17·1	1607	12·9	19·7	32·6	1050	1237	2287	
16	Complete Mineral Manure and single dressing Nitrate of Soda (= 43 lb. N.)	not limed	31·3	3061	37·0	24·2	61·2	2395	1577	3972	16
		limed ...	26·6	2432	25·5	21·6	47·1	1773	1317	3090	
17	Single dressing Nitrate of Soda (= 43 lb. N.)	not limed	19·1	1590	22·2	22·8	45·0	1182	1602	2784	17
		limed ...	20·2	1629	20·4	22·2	42·6	1340	1352	2692	
18	Potash, Sulphate of Soda, Magnesia, and double dressing Sulphate of Amm. (= 86 lb. N.) 1905 and since; following Minerals and Amm. Salts, supplying the constituents of 1 ton of Hay, 1865-1904	not limed	25·7	2349	5·2	36·0	41·2	401	2141	2542	18
		limed (6788 lb.)	29·7	2682	18.9	32·3	51·2	1338	2210	3548	
		limed (3951 lb.)	30·3	2746	16·3	27·1	43·4	1133	1893	3026	
19	Farmyard Dung in 1905 and every 4th year since (omitted in 1917); following Nitrate of Soda (= 43 lb. N.) and Minerals, 1872-1904	not limed	33·8	3040	23·3	31·1	54·4	1669	1723	3392	19
		limed (3150 lb.)	23·3	2128	8·7	23·6	32·3	683	1395	2078	
		limed (570 lb.)	25·7	2218	16·6	22·9	39·5	1142	1462	2604	
20	Farmyard Dung in 1905 and every 4th year since (omitted 1917); each intervening year, plot 20 receives Sulphate of Potash, Superphosphate and Nitrate of Soda (=26 lb. N.); following Nitrate of Potash and Superphosphate, 1872-1904	not limed	27·2	2468	26·3	25·1	51·4	2156	1824	3980	20
		limed (2772 lb.)	24·7	2382	31·5	21·4	52·9	2501	1575	4076	
		limed (570 lb.)	31·0	2842	33·6	23·1	56·7	2491	1713	4204	

Ground lime was applied to the Southern portion (limed) of the plots at the rate of 2,000 lb. to the acre in the Winter of 1903, 1907, 1915, and at the rate of 2,500 lb. to the acre in the Winter of 1920, except where otherwise stated.

Up to 1914 the limed and unlimed plot results were not separately given in the Annual Report, but the mean of the two was given. From 1915 onwards the separate figures are given.

1st and 2nd Hay Crops, 1922, were carted in very bad condition owing to the wet weather, some plots being much wetter than others. The Dry Matter figures give a truer indication of the relative yields of the different plots.

In 1921 there was no second crop.

The Park Grass Plots—*contd.*

BOTANICAL COMPOSITION, PER CENT. 1920 1st Crop.

Plot.	Manuring.	Liming.	Gramineæ.	Leguminosæ.	Other Orders.	"Other Orders" consist largely of	Plot.
3	Unmanured	Limed ...	61·20	11·75	27·06	Centaurea nigra	3
		Not limed	51·50	10·36	38·14	Centaurea nigra	
5-1	Unmanured, following double Amm. Salts, 1856-97	Not limed	73·43	1·36	25·20	Centaurea nigra	5-1
5-2	Super. and Sulph. Potash following double Amm. Salts, 1856-97 ...	Not limed	60·15	9·94	29·62	Luzula campestris (noticeable) ...	5-2
7	Complete Mineral Manure	Limed ...	42·82	44·21	12·98	Centaurea nigra	7
		Not limed	42·85	28·37	28·79	Achillea millefolium	
8	Mineral Manure (without Potash) ...	Limed ...	56·96	13·80	29·25	Centaurea nigra	8
		Not limed	48·46	17·22	34·33	Plantago lanceolata, Achillea millefolium and Centaurea nigra ...	
9	Complete Mineral Manure and double Amm. Salts	Limed ...	96·01	0·69	3·30	Rumex acetosa	9
		Not limed	95·04	—	4·97	Rumex acetosa	
10	Mineral Manure (without Potash) and double Amm. Salts	Limed ...	99·63	—	0·37	Rumex acetosa	10
		Not limed	99·06	—	0·93	Rumex acetosa	
14	Complete Mineral Manure and double Nitrate of Soda	Limed (sun)	95·13	0·89	3·97	Taraxacum vulgare	14
		,, (shade)	93·16	5·84	0·99	———	
		Not limed	97·88	—	2·13	Taraxacum vulgare	
15	As plot 7 following double Nitrate of Soda, 1858-75	Limed ...	72·64	11·49	15·86	Achillea millefolium, Plantago lanceolata	15
		Not limed	60·95	18·20	20·84	Achillea millefolium, Centaurea nigra	
16	As plot 7 and single Nitrate of Soda	Limed ...	92·47	1·54	5·98	Achillea millefolium	16
		Not limed	83·35	5·98	10·68	Taraxacum vulgare	
17	Single Nitrate of Soda	Limed ...	67·23	1·80	30·96	Centaurea nigra	17
		Not limed	62·46	0·29	37·26	———	
18	Potash, Sulphate Soda, Magnesia, and double Sulphate of Amm. 1905 and since	limed 6788 lb.	78·05	—	21·95	Rumex acetosa	18
		,, 3951 lb.	81·28	—	18·72	Rumex acetosa	
		Not limed	87·66	0·14	12·20	Rumex acetosa	
19	Farmyard Dung in 1905 and every 4th year since, omitted in 1917 ...	limed 3150 lb.	84·98	9·38	5·63	Achillea millefolium, Ranunculus spp.	19
		,, 570 lb.	71·47	18·63	9·91	Centaurea nigra, Ranunculus spp.	
		Not limed	76·38	15·25	8·36	Ranunculus spp.	
20	Farmyard Dung in 1905 and every 4th year since (omitted 1917), each intervening year Sulphate Potash, Super., and Nitrate of Soda ...	limed 2772 lb.	86·32	4·66	9·02	Centaurea nigra, Achillea millefolium, Anthriscus sylvestris ...	20
		,, 570 lb.	78·70	15·30	6·01	Centaurea nigra	
		Not limed	86·80	4·51	8·70	Achillea millefolium, Centaurea nigra	

WHEAT. BROADBALK FIELD, 1921.

Plot.	Manurial Treatment.	Top Portion.						Bottom Portion.					
		Dressed Grain.		Offal Grain per Acre.	Straw per Acre.	Total Straw per Acre.	Proportion of Total Grain to 100 of Total Straw.	Dressed Grain.		Offal Grain per Acre.	Straw per Acre.	Total Straw per Acre.	Proportion of Total Grain to 100 of Total Straw.
		Yield per Acre.	Weight per Bushel.					Yield per Acre.	Weight per Bushel.				
		Bush.	lb.	lb.	lb.	cwt.		Bush.	lb.	lb.	lb.	cwt.	
2*A*	Farmyard Manure	24·8	65·4	215	2457	29·1	56·4	26·2	65·8	200	2587	31·4	54·8
2*B*	Farmyard Manure	27·0	64·8	252	2811	37·4	47·8	26·4	66·0	229	2853	37·5	47·0
3	Unmanured	10·4	64·0	103	712	8·7	78·5	8·0	63·3	97	462	6·9	77·7
5	Complete Mineral Manure	7·9	63·3	83	518	6·8	76·4	7·7	63·5	91	484	6·5	79·5
6	As 5, and Single Amm. Salts	14·9	64·3	162	1418	17·6	56·7	12·2	64·3	138	996	13·5	61·0
7	As 5, and Double Amm. Salts	19·5	65·3	232	2302	28·8	46·6	16·1	64·8	258	1833	23·5	49·6
8	As 5, and Treble Amm. Salts	17·9	65·6	251	2422	33·4	38·1	19·8	65·3	311	2242	30·5	46·9
9	As 5, and Single Nitrate of Soda	15·9	64·3	145	1756	20·5	50·9	14·0	63·5	135	1574	18·1	50·4
10	Double Amm. Salts alone	16·5	63·9	184	1584	17·9	61·6	12·1	63·5	186	1130	14·3	59·8
11	As 10, and Superphosphate	9·4	62·8	239	1488	18·4	40·3	5·8	62·0	247	1090	15·7	34·5
12	As 10, and Super. and Sulph. Soda ...	16·0	63·5	259	2024	23·6	48·2	10·4	63·3	237	1500	19·8	40·2
13	As 10, and Super. and Sulph. Potash ...	20·2	64·4	205	2382	27·8	48·3	11·1	63·9	201	1710	24·0	33·8
14	As 10, and Super. and Sulph. Magnesia ...	17·8	64·1	301	2020	24·5	52·4	11·1	63·5	249	1460	19·8	43·1
15	Double Amm. Salts in Autumn and Minerals	22·6	64·8	277	2408	29·9	52·0	14·2	64·3	197	1472	21·3	46·5
16	Double Nitrate and Minerals	24·4	65·0	248	2942	34·1	48·0	17·2	64·8	246	2300	29·5	41·3
17	Minerals alone, or double Amm. Salts alone in	8·6	62·9	78	524	7·5	73·9	10·1	63·1	135	772	9·9	69·8
18	alternate years	22·8	64·8	246	2252	26·7	57·4	20·3	64·8	210	2068	24·7	55·1
19	Rape Cake alone	16·3	64·1	244	1538	19·3	59·5	15.4	64·1	216	1554	20·1	53·3
20	Mineral Manure (without Super.) and Amm. Salts	10·9	63·9	210	1627	20·7	39·1	—	—	—	—	—	—

WHEAT. BROADBALK FIELD, 1922.

Plot.	Manurial Treatment.	Top Portion.						Bottom Portion.						71 year Average 1852—1922.	
		Dressed Grain.		Offal Grain per Acre.	Straw per Acre.	Total Straw per Acre.	Proportion of Total Grain to 100 of Total Straw.	Dressed Grain.		Offal Grain per Acre.	Straw per Acre.	Total Straw per Acre.	Proportion of Total Grain to 100 of Total Straw.	Dressed Grain per Acre.	Total Straw per Acre.
		Yield per Acre.	Weight per Bushel.					Yield per Acre.	Weight per Bushel.						
		Bush.	lb.	lb.	lb.	cwt.		Bush.	lb.	lb.	lb.	cwt.		Bush.	cwt.
2*A*	Farmyard Manure	32·9	61·2	241	2204	31·8	63·2	24·7	62·0	727	2010	32·0	63·0	28·4*	32·8*
2*B*	Farmyard Manure ... ... — ...	36·0	61·3	255	2296	35·2	62·4	29·5	61·7	603	2070	35·9	60·2	34·3	34·6
3	Unmanured	9·0	60·5	98	704	8·8	65·3	6·2	60·5	101	476	6·6	64·8	12·1	9·9
5	Complete Mineral Manure	10·5	61·1	94	820	10·2	64·4	8·3	60·8	106	598	9·1	60·1	13·9	11·7
6	As 5, and Single Amm. Salts	17·3	60·8	132	1386	17·4	60·5	11·7	61·2	132	858	11·7	64·3	22·3	20·7
7	As 5, and Double Amm. Salts	29·0	60·8	246	2290	30·1	59·6	13·1	61·1	470	1702	23·7	47·8	30·9	32·2
8	As 5, and Treble Amm. Salts	25·4	60·8	439	1954	37·4	47·3	16·5	59·9	339	1416	29·4	40·4	35·1	40·2
9	As 5, and Single Nitrate of Soda	24·8	58·9	180	1878	23·4	62·5	13·7	59·2	142	920	14·3	59·4	24·5†	24·7†
10	Double Amm. Salts alone	9·2	59·4	305	850	15·1	50·3	4·3	58·8	306	634	11·9	41·7	19·1	18·0
11	As 10, and Superphosphate	4·2	57·6	327	974	18·9	26·7	1·3	57·3	189	478	13·3	17·7	21·5	21·7
12	As 10, and Super. and Sulph. Soda	7·4	59·0	371	1114	20·4	35·4	3·3	57·5	307	756	17·6	25·3	27·6	27·2
13	As 10, and Super. and Sulph. Potash	24·4	60·7	232	1968	26·9	56·9	14·5	61·1	300	1456	21·2	49·7	29·8	31·0
14	As 10, and Super. and Sulph. Magnesia ...	4·7	57·4	318	716	16·4	31·9	7·6	58·0	358	762	19·4	36·8	27·3	27·2
15	Double Amm. Salts in Autumn and Minerals ...	14·3	60·4	277	1420	23·1	44·0	8·1	60·2	300	1220	20·8	33·8	28·4	28·7
16	Double Nitrate and Minerals	27·0	60·7	405	2147	33·1	55·2	18·0	61·0	441	1868	31·0	44·2	30·7†	35·8†
17	Minerals alone, or Double Amm. Salts alone in	21·1	59·8	242	1786	23·5	57·2	17·1	59·8	280	1568	22·6	51·4	28·6	28·6
18	alternate years	13·3	59·9	101	995	13·4	59·7	9·4	60·3	259	970	14·1	52·1	14·3	12·4
19	Rape Cake alone	14·5	58·9	377	1212	21·1	52·0	9·5	58·3	338	1326	20·9	38·0	22.0‡	22·7‡
20	Mineral Manure (without Super.) and Amm. Salts	20·8	60·3	302	1419	21·6	64·3	—	—	—	—	—	—	18·6§	19·8§

* 23 years only, 1900-1922. † 38 years only, 1885-1922. ‡ 30 years only, 1893-1922. § 15 years only, 1906-1922 (no crop in 1912 and 1914).

RED CLOVER grown year after year on rich Garden Soil, Rothamsted Garden.

Hay, Dry Matter, and Nitrogen per Acre, 1921 and 1922.

Year.	No. of Cuttings.	As Hay.	Dry Matter.	Nitrogen.	Seed Sown.
		lb.	lb.	lb.	
1921	2	307	256	7	1921, March 31st, re-sown
1922	2	2399	1999	61	1922, May 12th, mended
Averages:					
25 years, 1854—1878		7664	6387	179	
25 years, 1879—1903		3924	3270	101	
50 years, 1854—1903		5794	4829	140	
15 years, 1904—1918		2888	2407	70	
4 years, 1919—1922		2001	1668	51	

WHEAT AFTER FALLOW (without Manure 1851, and since).

Hoos Field, 1921 and 1922.

	1921.	1922.	Average 67 years 1856-1922.
Dressed Grain {Yield per Acre—Bushels	15·20	6·93	15·22
Dressed Grain {Weight per Bushel—lb.	64·5	60·4	59·6
Offal Grain per Acre—lb.	110	189	52
Straw per Acre—lb.	1082	686	—
Total Straw per Acre—cwt.	13·2	10·3	13·1
Proportion of Total Grain to 100 of Total Straw	73·5	52·5	—

AVERAGE WHEAT YIELDS *of* VARIOUS COUNTRIES

Country.	Mean Yield per Acre 1901-10. Bushels.	Country.	Mean Yield per Acre 1901-10. Bushels.
Great Britain	31·6	Denmark	41·3
England	31·7	Argentine	10·6
Hertfordshire	30·5	Australia	10·1
France	20·2	Canada	19·5
Germany	29·1	United States	14·3
Belgium	35·1	Russia—European	10·0

NOTE.—Figures for Great Britain, England and Hertfordshire are taken from the Board of Agriculture's "Agricultural Statistics," Vol. 46. Other figures from "Annuaire International de Statistique Agricole," 1910-12, and converted at the rate of 60 lb. per bushel.

HOOS FIELD (formerly Potato Plots), 1921 and 1922. No Manure since 1901.

Plot.	Manuring given prior to 1901.	1921. WHEAT. Dressed Grain. Yield per Acre.	Weight per Bushel.	Offal Grain per Acre.	Straw per Acre.	Total Straw per Acre.	Proportion of total Grain to 100 of Total Straw.	1922. BARLEY. Dressed Grain. Yield per Acre.	Weight per Bush.	Offal Grain per Acre.	Straw per Acre.	Total Straw per Acre.	Proportion of Total Grain to 100 of Total Straw.
	Previous Cropping: Potatoes, 1876-1901; Barley, 1902 and 1903; Oats, 1904; Barley, 1905-1911; Oats, 1912; Barley. 1913 and 1914; Oats, 1915; Barley, 1916-19; Fallow, 1920.												
		Bush.	lb.	lb.	lb.	cwt.		Bush.	lb.	lb.	lb.	cwt.	
1	Unmanured	10·5	64·8	147	752	9·1	81·1	13·0	49·8	73	588	7·4	87·0
2	Unmanured 1882 to 1901, previously Dung only	17·4	65·1	219	1365	16·5	73·3	15·8	50·0	94	816	10·1	78·3
3	Dung 1883 to 1901	24·3	65·2	354	2061	24·6	70·2	21·6	49·9	89	933	11·3	92·0
4	Dung 1883 to 1901	26·9	65·3	276	2196	26·8	67.7	21·8	50·1	95	1044	12·6	83·9
	Previous Cropping: Potatoes, 1876-1901; Barley, 1902-1903; Oats, 1904; Plots 5, 7, 9, Cow Peas (failed), 1905; Plots 6, 8, 10, Red Clover, 1905; Red Clover, 1906-1911; Oats, 1912; Barley, 1913 and 1914; Oats, 1915; Barley, 1916-1919; Fallow, 1920.												
5	Ammonium Salts	18·6	65·5	298	1188	15·3	88·3	17·4	50·3	95	795	9·2	94·3
6	Nitrate of Soda	21·3	65·7	343	1629	20·3	76·6	17·8	50·2	93	816	9·6	91·5
7	Ammonium Salts and Mixed Minerals	24·1	65·5	226	1929	22·7	71·2	17·1	50·8	76	738	8·7	97·1
8	Nitrate of Soda and Mixed Minerals ...	25·2	65·7	270	1998	23·3	73·5	17·3	50·6	70	777	9·0	93·5
9	Superphosphate	26·9	65·8	232	2001	23·3	76·5	16·6	50·6	84	681	8·2	100·3
10	Mixed Minerals	26·0	65·9	216	1953	22·8	75·5	15·5	50·9	72	645	7·8	97·9

PERMANENT BARLEY PLOTS. Hoos Field, 1921, 1922.

PRODUCE PER ACRE.

Plot.	Manuring.	1921. Dressed Grain: Yield per Acre.	1921. Dressed Grain: Weight per Bushel.	1921. Offal Grain per Acre.	1921. Straw per Acre.	1921. Total Straw per Acre.	1921. Proportion of Total Grain to 100 of Total Straw.	1922. Dressed Grain: Yield per Acre.	1922. Dressed Grain: Weight per Bushel.	1922. Offal Grain per Acre.	1922. Straw per Acre.	1922. Total Straw per Acre.	1922. Proportion of Total Grain to 100 of Total Straw.	70 years Average Yield 1852—1922.† Dressed Grain per Acre.	70 years Average Yield 1852—1922.† Total Straw per Acre.
		Bush.	lb.	lb.	lb	cwt.		Bush.	lb.	lb.	lb.	cwt.		Bush.	cwt.
1 O	Unmanured	7·6	55·8	95	253	4·6	100·4	11·8	50·7	66	396	5·7	104·6	14·0	8·0
2 O	Superphosphate only	17·9	55·6	128	561	8·2	122·7	16·6	51·0	74	487	9·3	88·7	19·6	9·9
3 O	Alkali Salts only	13·0	56·4	114	440	7·5	101·3	11·9	49·8	55	459	8·0	71·9	15·0	8·8
4 O	Complete Minerals	16·7	56·3	125	630	9·5	99·8	15·1	52·0	74	608	9·0	85·4	19·8	11·1
5 O	Potash and Superphosphate ...	11·2	57·6	77	374	4·9	132·9	9·9	50·8	37	319	4·5	108·1	16·2	9·6
1 A	Ammonium Salts only	11·1	53·5	189	451	7·9	88·9	13·5	49·7	83	402	6·3	107·4	24·8	14·1
2 A	Superphosphate and Amm. Salts	27·1	54·8	396	1229	16·5	102·1	20·4	50·8	130	602	9·4	110·7	37·0	20·9
3 A	Alkali Salts and Amm. Salts ...	10·6	56·0	191	547	9·8	71·2	16·0	50·5	114	765	11·0	75·0	27·0	16·3
4 A	Complete Minerals and Amm. Salts	30·3	56·5	188	1411	18·4	92·1	30·7	51·5	90	921	13·1	114·2	40·6	24·0
5 A	Potash, Super. and Amm. Salts ...	22·7	57·9	85	1023	13·8	90·9	33·0	51·7	64	1205	14·4	109·8	34·9	22·2
1 AA	Nitrate of Soda only	7·9	53·3	215	457	8·2	69·7	14·1	50·3	109	517	8·8	82·9	25·3*	15·6*
2 AA	Super. and Nitrate of Soda ...	33·7	54·8	267	1441	17·9	105·2	30·6	51·9	88	957	13·7	109·7	39·9*	23·5*
3 AA	Alkali Salts and Nitrate of Soda	8·2	54·3	157	484	9·2	58·7	12·8	50·7	113	704	12·9	53·0	25·9*	16·8*
4 AA	Complete Minerals and Nitrate of Soda	33·2	56·6	171	1546	19·7	93·2	32·9	52·4	93	1260	17·1	94·6	39·2*	23·9*
1 AAS	As Plot 1 AA and Silicate of Soda	13·7	55·0	231	600	9·6	91·2	20·1	50·8	116	891	12·5	81·0	31·6*	18·7*
2 AAS	,, ,, 2 AA ,, ,,	33·0	55·3	243	1430	19·3	95·9	32·0	52·7	89	1100	14·5	109·1	41·0*	24·5*
3 AAS	,, ,, 3 AA ,, ,,	11·8	55·6	160	644	12·1	60·4	18·4	51·1	111	1161	15·4	60·9	32·9*	20·4*
4 AAS	,, ,, 4 AA ,, ,,	28·9	57·8	133	1342	19·6	81·9	36·8	53·2	87	1342	22·3	81·9	41·5*	26·0*
1 C	Rape Cake only	23·3	54·9	189	954	12·9	101·5	27·1	52·6	109	844	13·0	105·6	36·5	20·9
2 C	Superphosphate and Rape Cake	30·1	55·7	158	1139	15·0	109·2	33·8	51·8	74	974	13·6	119·9	38·8	22·3
3 C	Alkali Salts and Rape Cake ...	16·0	56·3	85	633	9·4	93·3	27·5	51·6	74	960	12·5	106·9	35·0	20·9
4 C	Complete Minerals and Rape Cake	18·1	57·1	75	673	10·6	93·5	34·2	52·2	70	1152	15·1	109·6	38·5	22·9
7—1	Unmanured (after dung 20 years, 1852—71)	11·0	56·0	107	394	7·5	85·6	17·7	52·1	72	631	9·0	98·1	24·0‡	14·1‡
7—2	Farmyard Manure	28·6	58·2	94	1509	20·4	76·7	31·4	52·0	99	1403	19·9	77·6	46·0	28·5
6—1	Unmanured	7·9	55·6	129	314	5·7	88·8	8·1	51·4	51	343	4·6	91·1	15·4	8·9
6—2	Ashes from Laboratory furnace ...	8·5	54·0	129	398	6·0	87·2	6·3	49·9	49	314	4·6	70·4	16·3	9·5
1 N	Nitrate of Soda only	8·4	52·5	184	490	7·6	73·2	13·7	51·0	95	616	9·3	76·3	30·0§	18·3§
2 N	,, ,, ,, ...	21·4	55·4	206	979	13·5	92·2	25·6	51·0	86	963	12·4	100·3	33·8§§	20·4§§

† 1912, all plots were fallowed. * 54 years, 1868—1922. ‡ 50 years, 1872—1922. § 69 years, 1853—1922. §§ 63 years, 1859—1922.

ROTATION PLOTS.

Little Hoos Field, 1921 and 1922.

Arranged to test the RESIDUAL VALUE of VARIOUS MANURES in year of application and one, two, and three years after.

Produce per acre.

Plot.	Manure per Acre from 1919 onwards.	Year of Last Dressing.	1921 (18th Season), Barley.						1922 (19th Season), Barley.					
			Dressed Grain.						Dressed Grain.					
			Yield per Acre.	Weight per Bush.	Offal Grain per Acre.	Straw per Acre.	Total Straw per Acre.	Proportion of Total Grain to 100 of Total Straw.	Yield per Acre.	Weight per Bush.	Offal Grain per Acre.	Straw per Acre.	Total Straw per Acre.	Proportion of Total Grain to 100 of Total Straw.
			Bush.	lb.	lb.	lb.	cwt.		Bush.	lb.	lb.	lb.	cwt.	
A 1	Control	—	*19·6*	*57·1*	*88*	*640*	*10·0*	*107·7*	*20·9*	*51.6*	*63*	*820*	*10·6*	*96·1*
2	Ordinary Dung, 16 tons	1920	39·4	58·8	76	1512	19·9	107·4	[*38·4*]	52·9	94	1404	[*19·2*]	[*98·9*]
3		1921	**37·7**	**58·9**	**57**	**1388**	**18·5**	**110·0**	35·7	53·0	82	1284	16·5	106·5
4		1922	25·9	58·0	67	844	13·5	103·8	**38·2**	**52·7**	**90**	**1372**	**17·8**	**105·9**
5		1915	31·2	57·4	85	1020	16·6	101·2	32·9	53·1	75	1232	15·3	106·7
B 1	Cake fed dung, 16 tons	1920	42·5	58·2	95	1804	21·3	107·7	38·1	52·7	84	1384	18·8	99·6
2	Control	—	*18·8*	*56·6*	*71*	*688*	*10·4*	*97·3*	*26·9*	*52·8*	*76*	*1004*	*13·1*	*101·6*
3	Cake fed dung, 16 tons	1921	**40·4**	**58·6**	**66**	**1628**	**20·0**	**108·9**	[*39·7*]	52·8	97	1484	[*20·2*]	[*97·0*]
4		1922	32·2	57.4	93	1236	16·3	106·2	[*44·2*]	**53·2**	**109**	**1660**	[*22·5*]	[*97·5*]
5		1915	30·9	57·8	72	1196	15·7	105·8	35·7	53·0	86	1364	17·3	102·0
C 1	Shoddy; Superphosphate; Sulphate of Potash ...	1920	22·0	56·0	118	940	12·1	99·9	16·6	51.9	95	696	9·9	86·8
2		1921	**30·8**	**56·3**	**166**	**1276**	**16·0**	**106·0**	19·2	52·5	79	816	11·2	87·0
3	Control	—	*19·7*	*56·0*	*113*	*880*	*11·2*	*96·9*	*22·8*	*52·5*	*72*	*918*	*11·8*	*96·1*
4	Shoddy; Superphosphate; Sulphate of Potash ...	1922	21·1	56·0	117	1164	13·8	84·1	**39·9**	**52·5**	**75**	**1448**	**18·4**	**105·3**
5		1919	23·2	56·4	102	1068	13·2	95·4	28·4	52·9	86	1132	14·5	97·6

D	1	Guano; Sulphate of Ammonia; Sulphate of Potash	1920	28·4	56·0	118	1252	15·4	99·3	17·9	52·5	80	732	10·7	85·0
	2		1921	**27·9**	**55·7**	**188**	**1348**	**17·1**	**90·8**	21·0	52·6	71	924	12·1	86·9
	3		1922	18·7	56·3	112	888	11·6	89·9	**35·6**	**53·0**	**113**	**1408**	**19·0**	**93·9**
	4	Control	—	*14·7*	*54·5*	*122*	*772*	*9.9*	*83·5*	*17·9*	*51·8*	*87*	*788*	*12·2*	*74·5*
	5	Guano; Sulphate of Ammonia; Sulphate of Potash	1919	19·1	54·9	131	992	12·6	83·7	18·4	52·1	84	824	11·9	78·0
E	1	Rape Dust; Superphosphate; Sulphate of Potash	1920	25·5	55·8	111	1092	13·4	102·5	19·4	50·6	83	872	11·0	86·6
	2		1921	**36·1**	**54·7**	**152**	**1524**	**17·3**	**109·8**	25·5	53·6	70	1068	13·8	93·1
	3		1922	13·1	56·0	123	588	7·8	97·6	**34·8**	**52·6**	**85**	**1328**	**17·0**	**100·8**
	4		1919	15·4	55·8	127	688	9·4	93·3	16·5	50·9	75	764	10·2	79·9
	5	Control	—	*21·4*	*55·9*	*134*	*872*	*11·9*	*99·8*	*19·7*	*53·1*	*63*	*824*	*11·8*	*84·2*
F	1	Control	—	*10·3*	*52·3*	*84*	*476*	*7·1*	*78·1*	*20·3*	*52·3*	*87*	*1048*	*13.1*	*77·8*
	2	Superphosphate; Sulphate of Ammonia; Sulphate of Potash	1920	22·1	55·5	94	896	11·9	98·5	23·6	52·6	73	960	12·1	96·9
	3		1921	**33·5**	**55·9**	**177**	**1480**	**17·8**	**102·9**	23·4	53·8	68	992	12·8	92·5
	4		1922	17·6	53·0	115	808	10·5	89·5	**37·8**	**52·5**	**97**	**1616**	**19·7**	**94·5**
	5		1919	16·4	55·5	122	896	11·7	78·7	19·6	52·0	70	892	12·0	81·3
G	1	Bone Meal; Sulphate of Ammonia; Sulphate of Potash	1920	20·4	53·7	115	844	11·6	93·5	22·6	53·7	96	1076	14·3	81·9
	2		1921	**24·1**	**54·6**	**123**	**1208**	**14·1**	**90·8**	28·0	52·8	76	1228	15·1	91·7
	3	Control	—	*22·9*	*54·9*	*93*	*1068*	*13·9*	*86·4*	*29·2*	*52·8*	*69*	*1292*	*15·3*	*93·9*
	4	Bone Meal; Sulphate of Ammonia; Sulphate of Potash	1922	22·8	54·5	91	1004	12·6	94·1	**36·2**	**53·8**	**103**	**1696**	**20·6**	**88·6**
	5		1919	20·8	53·8	100	944	13·2	82·3	25·5	52·3	79	1208	14·6	86·3
H	1	Basic Slag; Sulphate of Ammonia; Sulphate of Potash	1920	30·8	56·8	88	1184	14·8	111·2	28·1	52·7	87	1148	14·4	97·1
	2		1921	**34·1**	**55·8**	**150**	**1672**	**20·1**	**91·0**	29·5	53·2	82	1292	15·6	94·4
	3		1922	24·6	56·5	91	1040	13·9	94·9	**40·3**	**53·2**	**100**	**1844**	**22·0**	**90·8**
	4		1919	30·3	55·9	88	1236	15·2	104·5	30·4	53·8	64	1252	15·1	100·7
	5	Control	—	*27·8*	*55·4*	*106*	*1301*	*16·3*	*90·3*	*20·8*	*53·4*	*82*	*1020*	*12·5*	*85·6*

NOTES.—Since 1919 the manure for each plot (except of series A and B) has been rationed at 40 lb. Nitrogen, 100 lb. Calcium Phosphate, and 50 lb. Potash per acre. Each plot has been supplied with as much of its particular manure (shoddy, guano, &c.) as possible without exceeding the receipt in any of the three rationed ingredients. Any deficit in either of these three has then been made good by adding the necessary quantity of Sulphate of Ammonia, Superphosphate, or Sulphate of Potash.

Figures in italics denote unmanured plots. The yields on the plots to which the manure was applied in a given year are printed in heavy type.

Figures in square brackets are estimated yields.

STRAW EXPERIMENT, 1921.

Potatoes (Arran Chief). Sawpit Field.

Manure per Acre.	Yield per Acre. 1st Plot	2nd Plot	3rd Plot
	Tons	Tons	Tons
8 tons Rotted Straw Manure—Single Nitrogen ...	2·30	2·18	1·96
16 ,, ,, ,, ,, ,, ,, ...	2·48	2·63	2·16
32 ,, ,, ,, ,, ,, ,, ...	1·73	2·39	2·29
2 cwt. Sulphate of Ammonia	1·20	1·48	1·13
4 ,, ,, ,, ...	1·66	1·57	1·48
8 ,, ,, ,, ...	1·52	1·71	1·38
16 ,, ,, ,, ...	1·41	1·55	1·27
8 tons Rotted Straw Manure—Double Nitrogen ...	2·09	2·20	1·86
16 ,, ,, ,, ,, ,, ,, ...	3·32	2·59	2·50
32 ,, ,, ,, ,, ,, ,, ...	2·16	2·68	2·04
Control—No Manure	1·39	1·61	1·41
,, ,, ,, ...	1·52	1·45	1·39

Single Nitrogen represents 1 cwt. Sulphate of Ammonia added to 1 ton of straw.
Double Nitrogen represents 2 cwt. Sulphate of Ammonia added to 1 ton of straw.

RESIDUAL VALUE OF SLUDGE, 1921.

Long Hoos Field.

Treatment of Plots in 1920. Manure per Acre.	Dressed Grain. Yield per Acre. Bush. 1st Plot.	2nd Plot.	Dressed Grain. Weight per Bushel. lb. 1st Plot.	2nd Plot.	Offal Grain per Acre. lb. 1st Plot.	2nd Plot.	Straw per Acre. Straw. lb. 1st Plot.	2nd Plot.	Straw per Acre. Total Straw. cwt. 1st Plot.	2nd Plot.	Proportion of Total Grain to 100 of Total Straw. 1st Plot.	2nd Plot.
1921, Wheat (Red Standard) after Potatoes (1920).*												
Activated Sewage Sludge, 13·3 tons	29·8	27·9	64·0	64·1	371	406	2925	2624	32·7	30·8	62·2	63·6
Farmyard Dung 15 tons ...	34·8	31·6	64·0	64·1	296	371	2461	2600	30·3	29·7	74·5	72·0
Control	26·0	26·9	63·3	63·0	342	325	2299	1997	26·2	26·6	67·6	67·7
1921, Wheat (Red Standard) after Barley (1920).†												
Sulph. of Ammonia 1·45 cwt. ...	24·1		63·0		387		2738		31·1		54·6	
Activated Sewage Sludge, 2·7 tons	30·1		63·0		351		2857		31·4		64·1	
Control	27·2		62·5		405		2738		29·4		63·9	
Control	27·4		63·0		435		2333		30·3		63·7	

* In 1920 this set received a basal dressing of 6 cwt. Super. and 1 cwt. Nitrate of Ammonia per acre. No manure was given in 1921.

† In 1921 this set was manured as farm, *viz.*, 1 cwt. Sulphate of Ammonia and 1 cwt. Superphosphate per acre.

TOP DRESSING EXPERIMENTS.

Treatment of Plots and Quantities per Acre.	Dressed Grain						Offal Grain per Acre. lb.			Straw per Acre.						Proportion of Total Grain to 100 of Total Straw.		
	Yield per Acre Bushels.			Weight per Bushel lb.						Straw. lb.			Total Straw. cwt.					
	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3
Oats (Grey Winter).* Great Knott Field, 1921.																		
Super. 1½ cwt.	52·1	57·4	54·7	44·1	43·0	43·6	420	490	460	1900	2600	2540	31·8	37·5	40·2	76	71	63
Super. 1½ cwt.; Sul./Amm. 1½ cwt., applied March 4 ...	45·0	43·6	44·2	43·3	45·0	43·0	380	485	380	2020	1920	2620	31·6	35·5	37·9	66	61	54
Super. 1½ cwt.; Mur./Amm. 144 lb., applied March 4 ...	48·4	57·3	44·0	44·0	44·0	44·6	435	590	485	2280	2980	2480	37·1	47·0	36·4	62	59	60
No Manure	47·1	48·6	47·9	43·6	44·0	43·5	410	475	420	2060	2340	2200	31·1	36·1	33·4	71	65	67
Wheat (Red Standard). Great Harpenden Field, 1921.																		
Super. 200 lb.; Sul./Amm. 100 lb., applied March 2-3 ...	19·4	16·9	—	62·5	62·5	—	565	430	—	2350	1660	—	30·0	22·9	—	53	58	—
Super. 200 lb.; Sul./Amm. 200 lb., applied March 2-3 ...	20·3	15·4	—	62·5	62·5	—	540	443	—	2060	1900	—	27·1	25·6	—	60	49	—
Super. 200 lb.; Sul./Amm. 100 lb., applied March 2-3 and Sul./Amm. 100 lb., applied May 2 ...	21·3	13·8	—	62·5	62·5	—	495	350	—	2080	1450	—	27·2	20·7	—	60	52	—
Super. 200 lb.; Mur./Amm. 86 lb., applied March 2-3	17·7	15·7	—	62·0	62·0	—	430	370	—	1960	1700	—	24·4	22·8	—	56	53	—
Super. 200 lb.; N./Soda 140 lb., applied March 2-3 ...	15·2	16·9	—	62·5	62·0	—	355	415	—	1750	1980	—	21·4	24·0	—	54	55	—
Super. 200 lb.; Sul./Amm. 100 lb., applied May 2 ...	23·1	16·1	—	62·3	62·0	—	500	385	—	2660	1800	—	30·4	21·9	—	57	56	—
Super. 200 lb.; Sul./Amm. 200 lb., applied May 2 ...	23·8	17·4	—	62·5	62·5	—	500	485	—	2620	1900	—	30·6	22·6	—	58	62	—
Super. 200 lb.; Mur./Amm. 86 lb., applied May 2 ...	17·5	18·2	23·6	62·0	62·0	63·0	338	405	465	1700	1710	2500	21·3	22·6	27·8	60	61	63
Super. 200 lb.; Sul./Amm. 100 lb., applied April 4 ...	17·1	—	—	62·5	—	—	365	—	—	1780	—	—	24·0	—	—	53	—	—
No Manure	13·5	17·6	—	63·5	61·5	—	375	368	—	1320	1880	—	17·6	22·2	—	63	58	—
Super. 200 lb.	19·0	12·2	22·0	62·5	62·5	62·5	415	385	525	1830	1260	2540	22·7	17·1	28·1	63	60	60
Super. 200 lb.	—	16·6	—	—	61·0	—	—	360	—	—	1840	—	—	22·6	—	—	54	—
Wheat (Red Standard).† Foster's Field, 1922.																		
1 cwt. Sul./Amm. applied March 18	14·4	18·4	18·5	59·5	60·0	60·0	425	391	400	1425	1650	1650	17·0	19·2	19·9	67	70	68
1 cwt. Sul./Amm., applied April 20	18·3	21·3	15·8	59·5	60·3	60·0	394	394	353	1750	1850	1475	21·2	23·0	17·6	62	65	66
1 cwt. Sul./Amm., applied May 18	17·2	21·9	16·4	60·0	60·5	60·3	372	409	406	1625	1750	1425	19·4	21·4	17·9	65	72	70
93 lb. Mur./Amm., applied March 18	17·8	19·6	16·4	60·0	60·3	60·5	362	400	300	1550	1875	1375	19·2	22·8	18·0	66	62	64
186 lb. Mur./Amm., applied March 18	19·7	21·2	20·2	59·5	60·0	60·3	350	409	362	1700	1650	1800	21·0	20·8	21·7	65	72	65
2 cwt. Sul./Amm., applied March 18	20·0	20·8	18·3	60·3	60·0	60·0	438	503	369	1800	1950	1725	22·5	25·2	22·1	65	62	59
2 cwt. Sul./Amm., applied April 20	20·1	18·4	13·2	60·8	60·0	55·5	394	525	369	1700	1775	1475	21·4	24·3	19·0	67	60	52
2 cwt. Sul./Amm., applied May 18	19·4	17·9	17·2	60·0	60·5	60·0	425	506	441	1700	1675	1525	21·2	23·0	20·1	67	62	65
Basal Manuring only	13·4	15·0	11·9	59·8	60·0	60·0	328	391	297	1250	1325	1225	15·2	17·4	14·7	67	66	61
No Manure	12·9	16·7	13·2	60·0	60·3	59·5	378	328	331	1325	1525	1350	15·6	18·5	16·5	66	64	60
Barley (Plumage Archer). Long Hoos, 1922.																		
2 cwt. Super.; 1 cwt. Sul./Amm., applied May 9 ...	34·5	30·1	—	51·3	51·8	—	281	238	—	1650	1325	—	22·5	18·0	—	81	89	—
2 cwt. Super.; 2 cwt. Sul./Amm., applied May 9 ...	31·2	35·3	—	51·8	51·6	—	369	287	—	1600	1775	—	21·4	23·0	—	83	82	—
2 cwt. Super.; 98 lb. Mur./Amm., applied May 9 ...	27·7	30·4	—	51·0	51·3	—	256	263	—	1475	1500	—	20·5	21·4	—	73	76	—
2 cwt. Super.; 1 cwt. Mur./Amm., applied May 9 ...	25·7	32·3	—	52·0	54·3	—	250	350	—	1175	1575	—	18·5	23·0	—	77	82	—
2 cwt. Super.; 51½ lb. Urea, applied May 9	32·1	34·7	—	51·8	52·3	—	287	356	—	1575	1675	—	21·0	22·5	—	83	86	—
2 cwt. Super.	23·8	26·6	—	51·0	52·3	—	184	200	—	1175	1250	—	16·3	17·2	—	77	83	—
No Manure	23·6	31·2	—	52·0	51·3	—	200	244	—	1100	1650	—	16·5	22·1	—	77	75	—

* A luxuriant crop of mustard was ploughed in previous to the sowing of the Oats; hence the high yields on these plots.
† All plots (except the unmanured), received a basal dressing of 2 cwt. Super.; 1 cwt. S./Pot. per Acre.

Top Dressing Experiments—*contd.*

Root Crops. Great Harpenden Field, 1922.

Manuring per Acre.	Yield per Acre. 1st Plot. Tons.	Yield per Acre. 2nd Plot. Tons.
Potatoes (Kerr's Pink).		
Dunged Series: 15 tons Farmyard Dung per Acre—		
Super. 4 cwt., Sul./Pot. 1½ cwt.	6·73	5·41
Super. 4 cwt., Sul./Pot. 1½ cwt., Sul./Amm. 3 cwt. (half as Top Dressing)	7·92	9·17
Super. 4 cwt., Sul./Pot. 1½ cwt., Sul./Amm. 1½ cwt. ...	7·91	8·06
Super. 4 cwt., Sul./Pot. 1½ cwt., Sul. Amm. 4½ cwt.		
Super. 4 cwt., Sul./Pot. 1½ cwt., Sul./Amm. 3 cwt. ...	10·54	9·62
(1½ cwt. as Top Dressing)	10·08	9·37
Super. 4 cwt., Sul./Pot. 1½ cwt., Mur./Amm. 290 lb.	10·66	10·74
Undunged Series:		
Super. 6 cwt., Sul./Pot. 2 cwt.	6·10	4·90
Super. 6 cwt., Sul./Pot. 2 cwt., Sul./Amm. 3 cwt. (half as Top Dressing)	7·99	7·89
Super. 6 cwt., Sul./Pot. 2 cwt., Sul./Amm. 1½ cwt. ...	6·98	7·75
Super. 6 cwt., Sul./Pot. 2 cwt., Sul./Amm. 4½ cwt. (1½ cwt. as Top Dressing)	9·60	8·36
Super. 6 cwt.. Sul./Pot. 2 cwt., Sul./Amm. 3 cwt. ...	8·72	9·22
Super. 6 cwt., Sul./Pot. 2 cwt., Mur./Amm. 290 lb. ...	9·21	8·50
Swedes (Hurst's Monarch).		
589 lb. Slag,* 1 cwt. Sul./Pot. ... ... R	**25·13**	**28·24**
L	3·04	4·29
589 lb. Slag,* 1 cwt. Sul./Pot., 2 cwt. Sul./Amm. (as Top Dressing) ... ... R	**27·48**	**30·65**
L	3·82	4·87
589 lb. Slag,* 1 cwt. Sul./Pot., 10 tons Farmyard Dung ... ... R	**28·75**	**32·37**
L	4·22	4·12
589 lb. Slag,* 1 cwt. Sul./Pot., 10 tons Farmyard Dung, 2 cwt. Sul./Amm. (as Top Dressing) R	**32·61**	**32·43**
L	4·60	4·71

* Equivalent to 5 cwt. Super. R = Roots. L = Leaves.

SLAG EXPERIMENTS

(Details of the Slags used are given on p. 97.)

No. of Plot.	Treatment of Plot and Quantities per Acre.	1921 Yield per Acre. cwt. Series A	1921 Yield per Acre. cwt. Series B	1921 Dry Matter per Acre. lb. Series A	1921 Dry Matter per Acre. lb. Series B	1922 Yield per Acre. cwt. Series A	1922 Yield per Acre. cwt. Series B	1922 Dry Matter per Acre. lb. Series A	1922 Dry Matter per Acre. lb. Series B
	Hay. Great Field, 1921 and 1922								
1	High Grade Slag No. 12, 1170 lb. .	23·6	24·9	1981	2108	17·9	16·8	1154	1130
2	Open Hearth Slag No. 13, 1925 lb. (High Soluble)	20·1	27·8	1669	2262	13·2	20·0	876	1353
3	Open Hearth Slag No. 14, 1930 lb. (Low Soluble)	25·5	27·5	2024	2304	15·8	26·4	1064	1653
4	Gafsa Phosphate, 750 lb. ...	25·7	25·1	2016	2149	19·1	26·0	1268	1677
6	No Manure	23·6	29·2	1984	2323	16·3	23·9	1140	1583

Hay. Little Knott Field, 1921 and 1922

No. of Plot.	Treatment of Plot and Quantities per Acre.	1921 Yield per Acre. cwt.	1921 Dry Matter per Acre. lb.	1922 Yield per Acre. cwt.	1922 Dry Matter per Acre. lb.
1	High Grade, High Soluble Slag No. 15, 536 lb.	13·9	1342	14·3	1139
3	Low Grade, High Soluble Slag No. 16, 1113 lb.	16 8	1602	17·1	1378
4	High Grade Slag No. 17, 522 lb. ...	17·1	1650	15·2	1198
6	High Soluble Slag No. 18, 1113 lb.	15·7	1508	15·0	1117
7	Low Soluble Slag No. 19, 1104 lb.	14·5	1386	14·8	1184
2	Control. No Manure	15·7	1509	16·8	1308
5	Control. No Manure	16·1	1542	15·4	1233

Hay. Little Knott Field, 1922

No. of Plot.	Treatment of Plot and Quantities per Acre.	1922 Yield per Acre. cwt.	1922 Dry Matter per Acre. lb.
1	High Grade, High Soluble Slag No. 15, 536 lb. ...	13·5	1047
3	Low Grade, High Soluble Slag No. 16, 1113 lb. ...	12·9	1067
4	High Grade Slag No. 17, 522 lb.	12·8	1005
6	High Soluble Slag No, 18, 1113 lb.	13·2	1020
7	Low Soluble Slag No. 19, 1104 lb.	13·1	1070
2	Control. No Manure.	13·2	1086
5	Control. No Manure.	13·8	1083
8	Gafsa Phosphate, 422 lb.	22·6	1867
9	Nauru Phosphate, 280 lb.	20.9	1645

Hay. Great Field, 1922

No. of Plot.	Treatment of Plot and Quantities per Acre.	1922 Yield per Acre. cwt.	1922 Dry Matter per Acre. lb.
HL.1	High Soluble, Low Grade Slag No. 1, 872 lb.	16·7	1113
9	High Soluble, Low Grade Slag No. 1, 872 lb.	29·1	1741
3	Low Soluble, Low Grade Slag No. 2, 872 lb.	17·7	1197
6	Low Soluble, Low Grade Slag No. 2, 1225 lb.	23·0	1600
4	Gafsa Phosphate, 347 lb.	20·4	1399
7	Gafsa Phosphate 174 lb, Low Soluble, Low Grade Slag No. 2, 612 lb.	22·3	1499
2	Control. No Manure	17·0	1119
5	,, ,, ,, ...	22·7	1524
8	,, ,, ,, ...	22·6	1534

Hay. Great Field, 1922

No. of Plot.	Treatment of Plot and Quantities per Acre.	1922 Yield per Acre. cwt.	1922 Dry Matter per Acre. lb.
1C	High Soluble Slag No. 1, 872 lb	16·5	1095
2C	Low Soluble Slag No. 2, 1225 lb.	18·7	1301
3C	Gafsa Phosphate, 347 lb.	18·8	1284
4C	Tunisian Phosphate, 336 lb.	16·0	1036
5C	Florida Phosphate, 292 lb.	15·8	1042
7C	Nauru Phosphate, 263 lb.	15·2	1020
7D	,, ,, ,, ,, ...	15·5	985
8C	Nauru Phosphate Low Grade Slag No. 8, 411 lb. ...	15·4	1012
8D	,, ,, ,, ,, ,, ,, ,, ...	20·0	1287
C	Control. No Manure	10·9	730
D	,, ,, ,, ...	15·7	1013

Slag Experiments—*contd.*

Clover. West Barnfield, 1921 and 1922.

No. of Plot.	Treatment of Plots and Quantities per Acre.	1921 Yield per Acre. Series A	1921 Yield per Acre. Series B	1921 Dry Matter per Acre. Series A	1921 Dry Matter per Acre. Series B	1922 Yield per Acre. Series A	1922 Yield per Acre. Series B	1922 Dry Matter per Acre. Series A	1922 Dry Matter per Acre. Series B
		cwt.	cwt.	lb.	lb.	cwt.	cwt.	lb.	lb.
1	High Grade Slag No. 12, 1170 lb.	40·8	40·4	3521	3567	10·5	16·1	941	1418
2	Open Hearth, High Soluble Slag No. 13, 1925 lb. ...	43·0	38·7	3629	3470	18·5	13·7	1644	1183
3	Open Hearth, Low Soluble Slag No. 14, 1930 lb. ...	42·4	40·4	3720	3567	18·6	15·6	1679	1374
4	Gafsa Phosphate, 750 lb.	41·7	39·4	3654	3502	17·6	18·3	1604	1681
C	No Manure	43·6	39·4	3812	3593	16·3	18·3	1486	1630
C	,, ,, ...	40·8		3563		17·1		1490	

Barley (Plumage Archer). Long Hoos Field, 1922.

Treatment of Plots.	Dressed Grain. Yield per Acre in Bushels. Slag No. 20.	Slag No. 2.	Slag No. 1.	Dressed Grain. Weight per Bushel in lb. Slag No. 20.	Slag No. 2.	Slag No. 1.	Offal Grain per Acre. lb. Slag No. 20.	Slag No. 2.	Slag No. 1.	Straw per Acre. Straw. lb. Slag No. 20.	Slag No. 2.	Slag No. 1.	Straw per Acre. Total Straw. cwt. Slag No. 20.	Slag No. 2.	Slag. No. 1.	Proportion of Total Grain to 100 of Total Straw. Slag No. 20.	Slag No. 2.	Slag No. 1.
Basal Manuring, Slag, full quantity	36·0	26·0	28·7	51·3	51·4	51·8	197	162	231	1375	1175	1250	18·5	16·9	19·3	99	80	80
	35·1	31·7	25·5	52·8	52·0	51·0	200	172	213	1375	1238	1238	19·3	18·0	19·1	95	91	71
Basal Manuring, Slag, half quantity	29·9	25·5	32·5	51·9	51·8	51·5	194	169	241	1238	1113	1438	18·5	16·9	20·3	84	79	84
Gafsa Phosphate, 87 lb.	26·2	36·4	29·2	51·3	51·4	51·3	163	181	200	*875	1500	1275	*11·7	19·6	18.3	*115	93	83
Basal Manuring, Gafsa Phosphate, 174 lb.	34·8	25·2	27·5	51·6	52·3	52·0	231	162	209	1488	1088	1213	19·6	16·5	18·2	92	80	80
Basal Mauuring only	25·7	33·7	34 1	52·0	52·0	51·5	178	178	203	1063	1363	1388	15·8	18·3	18·9	85	94	93
No Manure	30·1	24·7	27·0	51·8	50·8	51·1	188	203	228	1363	1100	1263	19·2	15·9	18·8	81	82	77

Basal Manuring is 1 cwt. Sulphate of Potash; 1 cwt. Sulphate of Ammonia. Full Quantity Slag represents 636 lb. Slag No. 20, 602 lb. Slag No. 2 and 436 lb. Slag No. 1 per acre.

*There was a high wind blowing when this plot was threshed, hence the low figure for the yield of straw.

Slag Experiments—*contd.*

Swedes (Hurst's Monarch) Produce per Acre.
Great Harpenden Field, 1922.

Manuring per Acre.	Roots.			Leaves.		
	Slag No. 20.	Slag No. 2.	Slag No. 1.	Slag No. 20.	Slag No. 2.	Slag No. 1.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt., Slag full quantity ...	25·92	27·92	30·40	4·89	3·82	4·16
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt., Slag full quantity ...	32·08	30·31	30·40	4·01	5·04	4·20
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt., Slag half quantity, Gafsa Phosphate, 175 lb.	27·19	28·04	31·88	4·18	3·53	4·10
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt., Slag half quantity, Gafsa Phosphate, 175 lb.	28·21	29·78	28·82	4·28	4·16	4·27
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt., No. 7 Nauru Phosphate, 262½ lb.	30·96	26·43	26·50	4·49	4·00	3·98
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt., No. 3 Gafsa Phosphate, 350 lb.	27·83	31·12	28·46	3·95	4·58	4·66
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt.	27·21	31·45	25·74	4·16	5·02	3·99
No Manure	25·67	27·23	22·70	3·54	3·67	3·19

NOTE.—"Full Quantity" Slag is No. 20, 1275 lb. per Acre.
No. 2, 1225 ,, ,,
No. 1, 875 ,, ,,

Description of Slags Used.

No.	Type.	Total Phosphate as $Ca_3(PO_4)_2$	Solubility %
1	Open Hearth, L.G., H.S.	25·0	90·4
2	,, ,, L.G., L.S.	18·0	35·7
8	Phosphate, Slag Mixture	53·1	25·5
12	Talbot Process, H.G., H.S.	37·3	80·7
13	Open Hearth, L.G., H.S.	22·7	91·5
14	,, ,, L.G., L.S.	22·6	29·0
15	Talbot Process, H.G., H.S.	40·0	72·5
16	Open Hearth, L.G., H.S.	21·3	88·3
17	Bessemer, H.G., H.S.	42·5	77·2
18	Open Hearth, L.G., H.S.	20·8	67·0
19	,, ,, L.G., L.S.	20·2	21·0
20	,, ,, L.G., H.S.	17·2	78·8

L.G. = Low Grade. L.S. = Low Soluble.
H.G. = High Grade. H.S. = High Soluble.

POTASH EXPERIMENTS.

Manuring per Acre.	Dry Matter per Acre. 1st Plot	Dry Matter per Acre. 2nd Plot	Dry Matter per Acre. 3rd Plot	Yield per acre. 1st Plot	Yield per acre. 2nd Plot	Yield per acre. 3rd Plot

Clover. West Barn Field, 1922.

	lb.	lb.	lb.	cwt.	cwt.	cwt.
Control	1369	1273	1507	15·2	15·7	18·6
Sulphate of Potash, 210 lb.	1533	1929	2123	18·6	25·0	26·4
Cement Works' Dust, 511 lb.	1381	1710	1729	17·5	21·8	21·4

Potatoes (Arran Chief). Sawpit Field, 1921.

With Dung, 12 tons per Acre.

	Tons.	Tons.	Tons.
3 cwt. Super., 1½ cwt. Sulphate Ammonia, 470 lb. Sylvenite ...	3·57	*3·15	3·71
3 cwt. Super., 1½ cwt. Sulphate Ammonia, ...	3·55	*3·18	3·72
3 cwt. Super., 1½ cwt. Sulphate Ammonia, 1½ cwt. Sulphate Potash	3·67	4·27	3·88
3 cwt. Super., 1½ cwt. Sulphate Ammonia, 1½ cwt. Sulphate Potash, 95 lb. Sulphate Magnesium	*3·07	3·92	3·87
No Manure. Control	*2·28	3·48	3·18
3 cwt. Super., 1½ cwt. Sul. Amm., 1½ cwt. Muriate Potash	*2·31	4·24	3·97
3 cwt. Super., 1½ cwt. Sul. Amm., 1½ cwt. Muriate Potash, 84 lb. Sul. Magnesium	*2·43	3·90	4·15

Without Dung.

4 cwt. Super., 2 cwt. Sul. Amm., 625 lb. Sylvenite	3·49	4·04	3·11
4 cwt. Super., 2 cwt. Sul. Amm.	1·43	1·48	1·15
4 cwt. Super., 2 cwt. Sul. Amm., 2 cwt. Sul. Potash	3·48	4·28	3·52
4 cwt. Super., 2 cwt. Sul. Amm., 2 cwt. Sul. Pot., 127 lb. Sul. Mag.	3·85	4·26	3·25
No Manure. Control	1·24	1·72	1·65
4 cwt. Super., 2 cwt. Sul. Amm., 2 cwt. Muriate Potash	4·15	4·20	4·00
4 cwt. Super., 2 cwt. Sul. Amm., 2 cwt. Muriate Potash, 111 lb. Sul. Magnesium	4·27	3·95	3·63

Potatoes (Arran Chief). Sawpit Field, 1921.

4 cwt. Super., 2 cwt. Sulphate Ammonia, 232 lb. Sul. Potash ...	3·00	2·46	2·82
4 cwt. Super., 2 cwt. Sulphate Ammonia	1·16	0·98	0·89
4 cwt. Super., 2 cwt. Sulphate Ammonia, 5·4 cwt. Sylvenite ...	*1·93	3·36	3·04
Control. No Manure.	*0·73	1·10	1·16

Potatoes (Kerr's Pink). Great Harpenden Field, 1922.

With Dung 15 tons per Acre.

Basal Manuring (=Super. 4 cwt., Sul. Amm. 1·5 cwt. per Acre) ...	8·78	7·72	7·60
Sulphate Potash 183 lb. + Basal Manuring	9·49	9·72	9·45
Muriate Potash 148 lb. + Basal Manuring	9·22	9·60	8·82
Muriate Potash 148 lb. + Salt 497 lb. + Basal Manuring	9·84	9·49	9·14

Without Dung.

Basal (=Super. 6 cwt., Sulphate Ammonia 2 cwt. per Acre) ...	2·11	2·75	2·57
Sulphate Potash 244 lb. + Basal	7·88	8·96	8·06
Muriate Potash 197 lb. + Basal	8·62	8·73	7·62
Muriate Potash 197 lb. + Salt 662 lb. + Basal	8·45	8·27	8·43
Muriate Potash 197 lb. Sulphate Magnesium, 344 lb. + Basal ...	8·68	8·90	7·62
Muriate Potash 197 lb. Salt 662 lb. + Basal	8·66	8·02	7·51
No Manure	3·23	2·87	2·83
Sulphate Potash 244 lb. Sulphate Magnesium 344 lb. + Basal ...	9·25	8·79	7·11
Cement Works' Dust 614 lb. + Basal	7·47	6·66	6·38
Sylvenite 541 lb. + Basal	8·38	7·92	6·90

* On these plots the bouts were badly broken down due to extra hoeing on account of the growth of Wheatbind.

Mangolds (Prizewinner Yellow Globe). Great Harpenden Field, 1922.

Produce per Acre.

Manuring per Acre.	Roots. 1st Plot Tons.	Roots. 2nd Plot Tons.	Leaves. 1st Plot Tons.	Leaves. 2nd Plot Tons.
No. 9 Slag 4 cwt., Sulphate Ammonia 2 cwt., Sulphate Potash 2 cwt.	17·64	14·12	5·57	5·13
No. 9 Slag 4 cwt., Sulphate Ammonia 2 cwt.	10·45	11·61	4·73	4·94
No. 9 Slag 4 cwt., Sulphate Ammonia 2 cwt., Cement Works' Dust	18·75	18·25	5·61	5·96
No Manure	10·88		4·25	

POTATOES.

Relative Effects of Sulphates and Chlorides on different varieties.

Great Harpenden Field, 1922.

Variety.	Dunged Series.						Undunged Series.					
	Actual Weight of Potatoes.			Average Weight per Plant.			Actual Weight of Potatoes.			Average Weight per Plant.		
	Sulphate Row.	Chloride Row.	Basal Row.	Sulphate Row.	Chloride Row.	Basal Row.	Sulphate Row.	Chloride Row.	Basal Row.	Sulphate Row.	Chloride Row.	Basal Row.
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
	16	12¾	19¾	3·20	2·55	2·82	13½	17¾	4	2·25	2·54	1·00
Ajax	24	21¼	12¼	4·00	3·04	1·75	17¼	18	4½	2·46	3·00	0·64
	27	16½	33	3·86	4·13	4·71	7¼	23	4	2·42	3·29	0·67
	15¾	11¾	7¼	2·25	1·96	2·42	11¼	8¾	3¼	2·25	1·46	0·65
Arran Comrade	10¼	10¾	13	2·56	2·15	2·17	11¼	11¼	1½	1·88	2·25	0·30
	15½	10½	13	2·58	2·10	2·17	15	18	1¾	2·14	2·57	0·29
	19¼	19	19¼	3·21	2·71	2·75	10¼	13¾	7¾	1·46	1·96	1·11
British Queen	19¾	18¾	19¼	2·82	2·68	2·75	16½	11½	8¼	2·36	1·92	1·18
	26¾	25	23¼	3·82	4·17	3·32	11¾	15¾	3¾	1·96	2·63	0·75
	7¾	11	11¼	1·11	1·57	1·61	9	8	1	1·80	1·60	0·33
Duke of York ...	8¾	14	14	1·25	2·00	2·00	9¼	6½	2½	1·54	0·93	0·63
	13½	10½	14¾	2·25	1·75	2·46	6¼	10¼	1¼	1·04	1·46	0·42
	16½	14¾	10	2·36	2·11	1·43	12¼	9¾	1¾	2·04	1·63	0·35
Epicure ...	11½	13½	13½	1·64	1·93	2·25	13½	13¾	3¾	1·93	1·96	0·54
	16	18½	19½	2·29	2·64	2·79	11¾	12½	1	1·68	1·79	0·25
	13½	19½	21½	3·38	2·79	3·07	21½	17¼	4½	3·07	2·46	0·75
Great Scott ...	21½	24¾	19½	3·07	3·54	3·25	11¾	12¾	1¼	1·96	2·13	0·42
	27¼	29	24½	3·89	4·14	3·50	14¼	13¼	1	2·38	2·65	0·50
	24	20	21	3·43	3·33	3·50	16¾	19¼	4¾	2·79	2·75	0·68
Iron Duke ...	21	18½	16¼	3·00	3·08	2·32	10¾	20¼	4	1·79	2·89	1·00
	23¾	23¼	23	3·96	3·32	3·29	20	13	4½	2·86	3·25	0·64
	26	23¾	20¼	3·71	3·39	2·89	21½	18½	7¼	3·07	3·08	1·04
K. of K. ...	28½	27¾	21	4·07	4·63	4·20	—	—	—	—	—	—
	29½	29½	30¼	4·21	4·21	4·32	19¼	15½	5¾	2·75	3·10	0·82
	18¼	20¾	12	3·04	2·96	2·00	18¾	20¾	6½	2·68	2·96	0·93
Kerr's Pink ...	25	22¼	15	3·57	3·18	3·00	11½	19½	3¼	1·92	3·90	0·46
	26¾	30¼	15½	3·82	4·32	3·88	24¼	22	5	3·46	3·14	0·71
	18	14¼	30¾	2·57	2·04	1·96	9	9½	1¼	1·29	1·58	0·42
Nithsdale ...	15½	20½	20	2·21	2·93	2·86	12	15	1	2·00	2·14	0·33
	21½	26	14¼	3·58	3·71	3·56	14¼	14½	2½	2·04	2·07	0·63
	20¾	17	12¾	3·46	2·83	2·55	20	19½	7½	2·86	2·79	1·07
Tin Perfection	21¾	20¾	23¾	3·11	2·96	3·39	18¾	17¾	8½	2·68	2·54	1·21
	17½	19¼	23½	2·50	3·21	3·36	21¾	17	7	3·11	2·83	1·00
	25¾	23¾	25¼	4·29	3·39	4·21	26¾	20¼	9¼	3·82	2·89	1·32
Up-to-Date ...	20½	25¾	25½	2·93	3·68	3·64	20½	14¼	8¼	2·93	2·38	1·18
	29¾	28½	28¾	4·25	4·07	4·11	21¾	21	11	3·11	3·00	1·83

NOTE.—7 Plants were set in each Row.

Manures were:—Dunged Series: Basal Row: Super. 4 cwt.; Sulphate of Ammonia 1½ cwt.; Dung 15 tons per Acre.
Sulphate Row: Basal Manuring; Sulphate of Potash 184 lb. per Acre.
Chloride Row: Basal Manuring; Muriate of Potash 147 lb. per Acre.

Undunged Series: Basal Row: Super. 6 cwt.; Sulphate of Ammonia 2 cwt. per Acre.
Sulphate Row: Basal Manuring; Sulphate of Potash 244 lb. per Acre.
Chloride Row: Basal Manuring; Muriate of Potash 197 lb. per Acre.

Potatoes. Great Harpenden Field, 1922.

Comparison of Varieties.

	Ajax.	Arran Comrade.	British Queen.	Duke of York.	Epicure.	Great Scott.	Iron Duke.	K. of K.	Kerr's Pink.	Nithsdale.	Tin Perfection.	Up-to-Date
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Average weight of Potatoes lifted per row	16·21	10·54	16·08	8·86	11·88	16·58	16·89	21·62	17·63	13·49	17·49	21·47
Average weight per plant ...	2·70	1·90	2·43	1·50	1·81	2·79	2·67	3·28	2·73	2·23	2·62	3·17

Comparison of Manurial Treatment.

	Dunged Series.			Undunged Series.		
	Sulphate Row.	Chloride Row.	Basal Row.	Sulphate Row.	Chloride Row.	Basal Row.
	lb.	lb.	lb.	lb.	lb.	lb.
Average weight of Potatoes lifted per row	20·12	19·82	18·62	15·17	15·41	4·40
Average weight per plant ...	3·08	3·03	2·94	2·36	2·37	0·80

PROFESSOR BLACKMAN'S ELECTRO CULTURE EXPERIMENTS.

Clover. Great Knott Field, 1921.

Plots.	Yield per Acre
	cwt.
Electro-Culture	42·0
Control	41·2

Cereal Crops.

Plots.	Dressed Grain. Yield per Acre.	Dressed Grain. Weight per Bush.	Offal Grain per Acre.	Straw per Acre. Straw.	Straw per Acre. Total Straw.	Proportion of Total Grain to 100 of Total Straw.
	Bushels.	lb.	lb.	lb.	cwt.	
Oats (Grey Winter). Foster's Field, 1921.						
Electro-Culture	40·7	43·4	241	1543	19·3	93·0
Control I.	33·1	42·0	298	1220	14·9	101·4
Control II.	31·6	42·2	234	1102	14·6	96·0
Wheat (Red Standard). Foster's Field, 1922.						
Electro-Culture	15·4	61·4	234	1229	15·8	66·9
Control, North East ...	16·5	60·6	249	1272	15·5	72·1
Control, South East ...	17·2	61·8	231	1196	14·2	81·5
Barley (Plumage Archer). Great Knott Field, 1922.						
Electro-Culture	34·1	49·1	273	1808	22·2	78·2
Control	32·4	48·6	244	1840	22·3	72·8

BORON EXPERIMENT

Barley (Plumage Archer). Little Hoos, 1922.

Treatment of Plots.	Dressed Grain. Yield per Acre. Bushels.			Dressed Grain. Weight per Bushel. lb.			Offal Grain per Acre. lb.			Straw per Acre. Straw. lb.			Straw per Acre. Total Straw. cwt.			Proportion of Total Grain to 100 of Total Straw.		
	Series 1	Series 2	Series 3	Series 1	Series 2	Series 3	Series 1	Series 2	Series 3	Series 1	Series 2	Series 3	Series 1	Series 2	Series 3	Series 1	Series 2	Series 3
Boric Acid 20 lb. per acre ...	37·9	40·8	30·8	51·1	51·8	52·0	191	138	84	2025	1875	1850	24·6	23·2	22·1	77·4	86·5	68·2
Boric Acid 8 lb. per acre ...	36·5	40·0	41·3	51·5	52·0	52·0	169	113	150	1825	1800	1850	23·4	22·8	23·0	78·1	86·0	89·2
Control ...	34·9	40·8	38·6	50·9	52·4	52·5	156	134	119	1725	1775	1850	21·4	22·5	23·4	80·5	89·9	81·7

All plots received a basal dressing of Superphosphate 3 cwt.; Sulphate of Potash 1 cwt.; Sulphate of Ammonia 1½ cwt.

EXPERIMENTS WITH NITROGENOUS MANURES

Potatoes (Arran Chief). Sawpit Field, 1921.

Manure per Acre.	Yield per Acre. 1st Plot. Tons.	Yield per Acre. 2nd Plot. Tons.	Yield per Acre. 3rd Plot. Tons.
4 cwt. Super., 1 cwt. Sulphate Potash, 2 cwt. Sulphate Ammonia	2·27	2·24	2·43
4 cwt. Super., 1 cwt. Sulphate Potash	1·84	2·13	1·99
4 cwt. Super., 1 cwt. Sulphate Potash, 193 lb. Muriate Ammonia	2·18	2·67	2·61
Control	1·33	1·41	1·49
4 cwt. Super., 1 cwt. Sulphate Potash, 102 lb. Urea	*1·72	2·69	2·57

* The bouts on this plot were badly broken down due to extra hoeing on account of growth of Wheatbind.

Barley (Plumage Archer). Stackyard Field, 1921.

Manures per Acre.	Dressed Grain. Yield per Acre. Bushels.			Dressed Grain. Weight per Bushel. lb.			Offal Grain per Acre. lb.			Straw per Acre. Straw. lb.			Straw per Acre. Total Straw. cwt.			Proportion of Total Grain to 100 of Total Straw.		
	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3
1½ cwt. Super., 145lb. M./Amm.	40·4	34·8	—	54·7	55·5	—	197	135	—	2000	2000	—	23·5	25·9	—	91	71	—
1½ cwt. Super....	27·2	27·1	24·1	56·0	55·5	55·0	153	103	109	1325	1475	1350	17·1	18·4	17·2	88	78	75
1½ cwt. Super., 1½cwt. S./Amm.	38·3	36·5	30·2	55·7	55·2	54·2	144	175	194	1900	2050	1825	23·6	24·9	22·1	87	79	74
1½ cwt. Super., 76¾ lb. Urea ...	38·2	34·6	29·2	55·0	54·5	54·2	150	150	169	2000	2025	1775	24·2	24·7	21·3	83	74	73
No Manure ...	27·5	24·7	—	55·0	54·5	—	103	97	—	1400	1450	—	17·3	17·9	—	83	72	—

MALTING BARLEY EXPERIMENT.

Plumage Archer. Long Hoos Field, 1922.

Manures per Acre.	Dressed Grain. Yield per Acre. Bushels	Dressed Grain. Weight per Bushel. lb.	Offal Grain per Acre. lb.	Straw per Acre Straw. lb.	Straw per Acre Total Straw cwt.	Proportion of Total Grain to 100 of Total Straw.
Super. 3 cwt., Sul./Pot. 1½ cwt., Sul./Amm. 1 cwt.	36·0	50·8	163	1213	17·1	104
Super. 3 cwt., Sul./Pot. 1½ cwt., Mur./Amm. 93 lb.	35·7	51·0	169	1388	18·5	96
Super. 3 cwt., Sul./Pot. 1½ cwt. ...	31·0	50·8	188	1263	17·0	93
Super. 3 cwt., Sul./Amm. 1 cwt. ...	30·0	50·3	175	975	14·1	107
Super. 3 cwt., Sul./Amm. 1 cwt., Mur./ Pot. 1½ cwt.*	34·8	50·0	206	not	recor	ded.
Sul./Amm. 1 cwt., Sul./Pot. 1½ cwt.	36·8	50·3	191	1438	19·9	92
No Manure	28·6	50·5	184	1125	15·5	94

*Muriate of Potash applied on April 3rd. Other Manures on March 24th.

MISCELLANEOUS EXPERIMENTS.

Clover. Hoos Field, 1921 and 1922.

(Formerly Barley after Alsike).

Plot.	Manures per Acre.	Yield per Acre. 1921. cwt.	Yield per Acre. 1922. cwt.
1	Slag 8 cwt., Lime 10 cwt.	45·3	17·4
2	Farmyard Manure 14 tons, Super. 5 cwt., Lime 10 cwt.	53·8	17·9
3	Lime 10 cwt.	35·9	17·6
4	Super. 5 cwt., Lime 10 cwt., Sulph. Potash 1½ cwt. ...	40·6	19·6
5	Super. 5 cwt., Lime 10 cwt.	45·3	13·0
6	Lime 10 cwt.	41·1	13·0
7	Farmyard Manure 14 tons, Lime 10 cwt.	54·5	16·7
8	Slag 8 cwt.	42·9	11·4
9	Farmyard Manure 14 tons, Super. 5 cwt.	50·5	17·2
10	*Control*	*36·8*	*14·1*
11	Super. 5 cwt., Sulph. Potash 1½ cwt.	45·1	20·3
12	Super. 5 cwt.	49·1	14·3
13	*Control*	*36·6*	*9·4*
14	Farmyard Manure 14 tons	46·2	10·7
15	Horse Dung 14 tons, Lime 10 cwt.	35·3	6·7
16	*Control*	*35·5*	*7·1*
17	Horse Dung 14 tons	54·9	11·6
18	Super. 5 cwt.	39·7	6·3
19	Cattle Dung 14 tons, Lime 10 cwt.	50·5	13·0
20	*Control*	*33·3*	*3·6*
21	Cattle Dung 14 tons	41·5	5·8

Manures applied and Clover sown in 1920.

Barley. Hoos Field. Leguminous Strips, 1921, 1922.

Description of Plot.	Manurial Treatment	1921. Dressed Grain. Yield per Acre.	1921. Dressed Grain. Weight per Bushel	1921. Offal Grain per Acre.	1921. Straw per Acre.	1921. Total Straw per Acre.	1921. Proportion of Total Grain to 100 of Total Straw.	1922. Dressed Grain. Yield per Acre.	1922. Dressed Grain. Weight per Bush.	1922. Offal Grain per Acre.	1922. Straw per Acre.	1922. Total Straw per Acre.	1922. Proportion of Total Grain to 100 of Total Straw.
		Bush.	lb.	lb.	lb.	cwt.		Bush.	lb.	lb.	lb.	cwt.	
After Lucerne ...	Sulphate Amm. 1½ cwt. ...	14·8	56·5	134	688	10·2	85·5	27·2	51·4	188	1921	22·7	62·3
	S. Amm. 1½ cwt. Super. 3 cwt.	37·8	57·3	154	1310	18·0	115·4	41·2	52·0	161	1884	22·2	92·6
After Red Clover	Sulphate Amm. 1½ cwt. ...	12·1	56·4	122	555	8·4	85·2	25·2	50·6	134	1556	18 1	69·3
	S.Amm. 1½ cwt.; Super. 3 cwt.	31·1	57·4	134	1037	15·7	109·0	35·4	51·5	109	1579	18·0	96·0
After Alsike ...	Sulphate Amm. 1½ cwt. ...	11·0	56·3	100	557	8·3	77·6	25·9	50·9	125	1481	17·2	74·8
	S.Amm. 1½ cwt.; Super. 3 cwt.	28·7	57·8	137	871	15·2	105·4	33·6	52·0	92	1421	16·5	99·6

Leguminous crops ploughed in November, 1911.

OUTSIDE CENTRES—MALTING BARLEY EXPERIMENTS.

Yield in bushels per acre; nitrogen expressed as per cent. of dry matter; value in shillings per quarter assigned by the expert valuation committee.

Treatment.	Rothamsted.			Cawkwell.			Wellingore.			Barneyhill.			Milverton.			Dereham.		
	Bushels.	Per cent. Nitrogen.	Value.	Bushels.	Per cent. Nitrogen.	Value.	Bushels.	Per cent. Nitrogen.	Value.	Bushels.	Per cent. Nitrogen.	Value.	Bushels.	Per cent. Nitrogen.	Value.	Bushels.	Per cent. Nitrogen.	Value.
			s.			s.			s.			s.			s.			s.
No Manure	25·8	1·60	36	25·2	1·56	28	36·1	1·76	36	78·5	1·36	48	26·0	1·53	45	36·7	1·62	31
Complete Manure	32·6	1·64	31	30·9	1·57	30	39·0	1·80	36	89·0	1·47	48	—	—	—	41·0	1·67	31
No Potash	27·0	1·69	31	22·6	1·49	30	43·5	1·78	36	84·0	1·50	48	27·2*	1.64	48	42·0	1·62	31
No Phosphate	33·0	1·63	32	28·8	1·49	30	40·5	1·89	32	85·0	1·47	45	—	—	—	36·0	1·69	31
No Nitrogen	28·2	1·58	31	23·1	1·50	30	37·3	1·72	40	75·5	1·38	53	23·3	1·48	55	30·0	1·66	31
	Woburn.			Orwell Park.			Walcott.			Eyton.			Dunmow.			Eye.		
			s.			s.			s.			s.			s.			s.
No Manure	42·5	1·78	27	16·2	1·43	65	56·9	1·70	30	36·0	1·85	32	51·0	1·75	42	39·5	2·11	30
Complete Manure	44·7	2·09	27	21·6	1·52	65	60·3	1·88	30	28·0	1·90	32	49·5	1·75	42	43·5	2·17	30
No Potash	41·8	2·10	27	24·6	1·53	64	58·7	1·79	30	45·2	2·10	32	47·0	1·85	42	44·1	2·13	30
No Phosphate	39·9	1·91	27	27·9	1·55	64	61·3	1·88	30	44·5	1·87	40	49·0	1·75	42	50·9	2·23	30
No Nitrogen	45·0	1·87	27	18·2	1·51	60	60·8	1·72	30	48·0	1·90	40	45·0	1·78	42	59·1	2·02	30

* Superphosphate only given in this case.

Lawes Agricultural Trust

TRUSTEES

COMMITTEE OF MANAGEMENT

The Incorporated Society for Extending the Rothamsted Experiments

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The purpose of this Society is to collect much needed funds for continuing and extending the work of the Rothamsted Station.

MEMBERS OF COUNCIL

Bankers: Messrs. Coutts & Co., 15 Lombard Street, E.C.3.

Auditors: Messrs. W. B. Keen & Co., 23 Queen Victoria Street, E.C.4.

Memoranda

Memoranda

Memoranda